# NAVAL WAR GAMES : A STUDY AND IMPLEMENTATION


*By*

H. BHARGAVA

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR



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# NAVAL WAR GAMES : A STUDY AND IMPLEMENTATION

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H. BHARGAVA

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It is not pleasant to think that Warfare is fundamental to the nature of man, and indeed it may not necessarily be so. However, through all recorded history we find this unfortunate trend.

Perhaps someday the present effort will become pointless/ irrelevant i.e. when wars will no longer exist.

In that light, this work is dedicated to its own obsolescence.

We often fail
to realise
how little we know
about a thing
until we attempt
to simulate it
on a computer.

– Donald E. Knuth

## CERTIFICATE

This is to certify that the work entitled, 'NAVAL WAR GAMES : A STUDY AND IMPLEMENTATION by Lt. H. Bhargava, I.N., has been carried out under our supervision and has not been submitted elsewhere for a degree.


RMKSinha

R.M.K. Sinha
Assistant Professor
Electrical Engineering and
Computer Science
Indian Institute of Technology
Kanpur 208016

MSKrishnamoorthy

M.S. Krishnamoorthy
Assistant Professor
Computer Science Program
Indian Institute of Technology
Kanpur 208016


July 26, 1979

POST GRADUATE OFFICE
This thesis has been approved for the award of the Degree of Master of Technology (M.Tech.) in accordance with the regulations of the Indian Institute of Technology Kanpur
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- HB

Kanpur
30 JUL 79

# TABLE OF CONTENTS

## LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Naval War Games are studied and one game namely the Anti-Ship Missile Defence is developed and implemented on a computer in this thesis. The game provides flexibility and interaction in scenario definition. The game is played by ship and missile commanders who man independent stations. The game controller controls the game. In addition, a model for the Naval War Gaming System for the Navy is also developed.

# I. INTRODUCTION

Warfare is a human phenomenon. May be, man against man wars are no longer fought, but wars exist only because the human race exists.

Computers have helped man and taken over many of his pursuits and activities, War Gaming is one of them.

This work presents a study and implementation of a War Gaming System for Navy. The problem considered for simulation and implementation is of defending the ship against an attacking sea-skimmer cruise missile at sea. In addition, a model for the bigger Naval War Gaming System is also developed.

## 1-2. WHAT IS WAR GAMING?

To answer what is War Gaming, let us first see what is Gaming?

Gaming is a means of studying activities in which alternative courses of competitive or variable actions are possible.

Coming to a definition for War Gaming, James Cannon [CANN 78] of the US Army War College in his master's thesis defines War Gaming as a process which 'provides a meaningful and viable method for combining military expertise with modern analytic techniques to assist defense planners and decision makers in making rational choices among complex alternatives'. Hardy [HARD 77] describes War Game as

'a dynamic simulation of military combat executed in such a way that one or more human participants can exercise control over the activities of simulated forces'.

War Gaming is not a new technique. It is probably as old as the history of warfare. Good historical write-ups exist in literature [HAUS 71, TORG 70], wherein mention is made of Early Chess (3000 B.C., India). Sand Modelling (8th century to date), GO (18th century, Japan), War Chess (1780,Germany), Kriegsspiel (1872, Prussia), etc.

However, with the onset of digital computers in 1950's, computer assisted war gaming has evolved as an important and powerful technique/aid to military decision making. In recent years, war gaming techniques have provided a way to tackle elusive problems not only in military context but also in management, education, politics, diplomacy, arms control, peace and other deep concerns of our times [HAUS 71, QUAD 68].

1-2. <u>WARFARE AT SEA</u>

No matter how extensive has the test firing been, the ultimate (and real) evaluation of a weapon system comes about only when it is deployed in a real environment i.e., war. Ship-ship <u>missiles</u> were developed by USSR as early as 1950's. The world knew about it. But its potential threat was realised by the world only after the 1967-war.

It has been established that a major threat for warships at sea is the cruise missile [TUCK 79, ROGE 78]. A large ship forms an ideal target for a cruise missile. It is relatively slow moving, and has a low manoeuvrability. It presents a bigger radar cross-section (RCS) and generates much more electromagnetic radiation (including radiant energy) than a smaller ship, and thus enhances the performance of most types of target acquisition sensors. In fact, after the 1967 war, the Israelis disposed of their larger ships and re-equipped their Navy mainly with small gun boats fitted with Gabriel anti-ship missiles [SUND76].

With the development of sea-skimmer-missiles in 70's, the 'killer-weapon' role has been taken over by the sea-skimmers.

In the second half of 1967, the Egyptian Navy sank the Israeli destroyer ELIAT off Port Said by using Soviet Styx cruise missiles. It was not until the sinking of the ELIAT in 1967, however, that the potential effectiveness of these missiles was suddenly recognised globally and naval planners throughout the world began crash programs to seak a counter.

G.S. Sundaram of the International Defense Review has stated [SUND 76] that during the 1971 Indo-Pakistan conflict, Indian Navy successfully deployed cruise missiles to score near-hundred percent hits on Pakistani targets.

These two real life evaluations (revealations too!) of cruise missiles led to the accelerated development of necessary Electronic Warfare (EW) capabilities to counter the cruise missiles. The US-aided Israeli EW development and subsequent deployment brought about spectacular results in the 1973 Yom Kippur War. (We shall deal with the tactics deployed in a later section/chapter). Once again, quoting from Sundaram's paper [SUND 76], out of a combined total of 50 Styx missiles fired by the Arab navies, not one hit its target. The statistics of cruise-missile deployment in combat, is given in Table 1.

| | No EW Technique Used | | With EW Techniques |
|---|---|---|---|
| | 1967 Arab-Israeli War | 1971 Indo-Pak conflict | 1973 Yom Kippur War |
| Percentage of cruise missiles that scored 'hits'. | 100 | 92.3 | Zero |

Table 1: EW Effectiveness.

ꟷW was looked upon with much scepticism, and its importance was never really fully appreciated. In fact, until the 1973 war, no Navy had really experienced the full effectiveness of ECM in combat.

Richard Hartman, Editor of Electronic Warfare magazine writes [HART 78], 'Together, EW and hard skill weapons, each in its most efficient form for the platform assigned, can and should increase the life expectancy of a ship in combat by several orders of magnitude over that which might be expected from either descipline alone.'

1-3. THE PROBLEM

With the above introductory remarks, let us look at the Problem investigated into. Present work can be categorized into two channels:

(a) Development of a model for the NWGS.

(b) Simulation of Anti Ship Missile Defense (ASMD).

1-3.1 Model for NWGS: An effort has been made to develop a model for the Naval War Gaming System (NWGS) with an open mind. The model should be viewed as a proposal. Suitable modifications/ammendments may have to be made.

With the given time and resources for investigation, it was not possible to develop detailed software for implementation of the NWGS. Neither was it intended. The NWGS model has been developed as a framework, a basis, using which a War Gaming System for our Navy could be configured.

It may be mentioned that the proposal for a War Gaming System to be installed at the US Naval War College took one year of dedicated team work [HARD 77] to be finalised. And the implementation of the Gaming System based on the proposal may take anywhere between 4 to 5 years.

The framework for the model is presented in Chapter 2.

1-3.2 Simulation of ASMD: Major part of present work involves simulation of Anti Ship Missile Defense (ASMD). Apart from the reasons stipulated earlier, the sea-skimmer was chosen as the attacking-missile for following reasons:

(a) It exists as a grave threat at sea.

(b) It is possessed by our neighbours [FLIG 78] and hence is highly relevant.

The defensive methods available against cruise missiles can be considered under three groups [SCRI 76]:

(a) Disruption: principally by jamming

(b) Deception (or Dilution): by jamming or decoys

(c) Destruction: by anti-missile systems.

Disruption is mainly relevant to active radar systems. It involves deployment of either of the following strategies:

(a) Noise Jamming: not of much benefit.

(b) Unlocking Techniques such as gate stealing and disruption of conical-scan patterns.

(c) Jamming of Radio Altimeter (still in research stages).

(d) Use of smoke against TV-aimed weapons.

Deception and dilution offer perhaps the most profitable field for ingenuity. The levels of discrimination and perspicacity that can be built into a missile's homing system are inevitably limited. Therefore, the opportunities for creating confusion by the use of decoys or deceptive jamming techniques can be exploited to a great extent. The principle aim of deception/dilution systems is to confuse the attacking force or its weapons, as to which are the true targets. A word of caution is due here. Timing is all important in deception techniques [SCHL 61]. The deception must be perpetrated before the system has locked on to the true target. Sensors and decoys have to have minimum 'reaction time'.

Defense by destruction using anti-missile systems has the following drawbacks:

(a) Anti-missile missiles need early enough warning to enable engagement.

(b) All missile systems have a rather 'long' minimum intercept range due to the need to recover from the launch phase.

(c) Reduced target-handling capacity due to the need for early acquisition and a long engagement cycle.

(d) Revolutionary anti-missile defense techniques like the 'Beam Weapons' [ROBI 78] are suited for large platforms like Aircraft carriers. Their use on frigate-size ships is yet to be seen.

Average frigate is thus unlikely to carry enough missile systems to be able to handle by this means alone the rate and scale of attack that may be threatened.

It will be clear that the obvious choice for the defensive method is 'deception'.

Coming to the choice between jamming and/or decoy, decoys (in particular chaff) were chosen for implementation. Using jamming to deceive the missile would have been equally relevant and realistic, but due to the nature of classified data associated with jammers and jamming techniques, chaff was chosen instead. In case further work is done in a classified environment, certain suggestions have been listed in Chapter 7.

The present work involves simulation of ship-defense against a sea-skimmer missile using chaff as the deception device. Chapters 3 to 6 give a detailed description of the simulation and implementation.

## 1-4. THE APPROACH AND ASSUMPTIONS

In simulating the ASMD problem, following design desirables were taken as guidelines:

(a) The simulation model should be simple and easy to understand and implement.

(b) It should be realistic.

(c) It should have provision for player interaction.

(d) It should have total flexibility in game scenario definition. Such that in future, Naval commanders could chose their platforms and the sensors/weapons-fit thereon at will.

With above in mind, the following approach was adopted in developing the ASMD simulation model.

(a) Two-Dimensional Model: For simulation purposes, the entire war game was restricted to the two dimensions of space- namely a horizontal plane on sea-surface. It will be appreciated that since sea-skimmers do not travel at an altitude higher than that of the ship, this assumption does not introduce inaccuracies. Moreover, we know that ships do not 'fly' (barring hovercraft). At a later stage, when aircraft are introduced into the Game, the 3-dimensional model for respective aircraft can always be considered without drastic alteration to existing model (at best one or two subprograms may need alteration). The 2-dimensional model is simple, straightforward and easy to understand and implement.

(b) X-Y Point Targets: All targets were simulated as X-Y points in the cartesian coordinate system. However, care was taken to distinguish a large target (say a ship) from a small target (say a missile).

(c) Missile/Ship Movement: It was assumed that during every time step (DELT), the missile/ship move in a straight line. The necessary course corrections can thus be applied every DELT. By choosing an appropriate

DELT, a realistic movement of ship and missile was simulated. Missile path was simulated based on the objective that it should always head for the target.

(d) Scenario Definition: Before commencement of the Game, the players select their platform, weapons and sensors from the available data base and assign it to the units taking part in the Game. The player has been given total freedom in selection subject to a maximum that his ship can take.

(e) Game Progress and Record: The war game progresses every DELT. During each DELT, actions such as movement of ship, missile, and chaff cloud (if present), target search and detection, target engagement (if applicable) and decision making (based on built-in tactics) etc. are carried out. Game status in terms of missile and ship positions, weapons state, detection/acquisition information etc. is printed out as a hard copy.

Detailed description of the models developed on above guidelines is presented in Chapters 4 and 5. Chapter 3 describes the ASMD data base, whereas Chapter 6 gives a user-oriented picture of the ASMD simulation.

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## 2. DEVELOPMENT OF A MODEL FOR NWGS

Models are representations of real life situations. If they were as complex and difficult to control as reality, there would be no advantage in their use. Therefore, simplicity is of prime concern in modelling. In building up the model for the NWGS, the following guidelines were observed:

(a) The model should provide the Navy with basic building blocks for the NWGS.

(b) The model should facilitate/enable modular and concurrent development of NWGS modules.

(c) The model should have scope for future additions/deletions/developments.

The model presented here should best be viewed as a list of 'jobs-to-be-done' alongwith suitable suggestions on 'how-to-go-about-it?'

### 2-1. SYSTEM SIMULATORS

The NWGS will have a large variety of platforms, sensors and weapons system simulators. These system simulators will be central to NWGS. To a large extent, the realism and accuracy of NWGS depends upon how accurate the system simulators are.

The system simulators accept data from the NWGS data bases and produce simulated outputs same as the actual system being simulated would have done. For example, the radar system simulator may accept inputs describing power

output, frequency of operation, antenna gain, target RCS, and other such parameters and produce an output implying whether target is within radar detection zone or not. Still more, it could produce a detection probability curve as a function of height, range and size of the target.

The system simulators are computer models that translate parameters describing technical characteristics and environmental conditions of a weapon/sensor/platform system into operational performance characteristics.

The outputs produced by the system simulators will be utilized by the Engagement Assessment Modules for further game progress.

A representative list of systems for which system simulators will have to be 'written' is shown in Table II, III and IV. The list is in no way complete/exhaustive. But it has been prepared keeping in mind simplicity of the model and capabilities of Navies in South-East Asia [JANE 77, JANE 78A,B, JANE 79].

## 2-2. ENGAGEMENT ASSESSMENT MODULES

These are computer simulation models that can be 'called' up as necessary to translate actions (outputted by system simulators) into combat outcomes. One kind of engagement assessment module might, for example, use the detection probability curve produced for a radar by the

Table II: Representative Platforms that may be Included in the NWGS

PLATFORMS

General Purpose Frigates

Missile Corvettes

Cruisers

Aircraft Carriers

Fixed Wing Aircraft

Rotary Wing Aircraft

Minecraft

Shore Patrol Vessels

Fast Patrol Boats

Landing Craft

Refuelling Ships

Submarines

Table III: Representative Sensors that may be Included in the NWGS

SENSORS

ESM/ECM/ECCM

EW Intercept Receivers

Radars (L,S and X bands)

Dipped Sonars

IFF Equipment

Visual reconnaissance

Infrared sensors

Acoustic systems

HF/DF

Table IV: Representative Weapons that may be Included in the NWGS

WEAPONS

Surface-to-surface missiles
Subsurface-to-surface missiles
Surface-to-subsurface missiles
Subsurface-to-subsurface missiles
Surface-to-air missiles
Air-to-surface missiles
Air-to-air missiles
Subsurface-to-air missiles
Antiradiation missiles
Naval Guns
Aircraft guns
Shore-based guns
Aerial guns
Torpedoes
Anti-submarine rockets
Ahead-thrown antisubmarine weapons
Depth charges
Mines
Chaffs
Decoys/smoke screens

system simulators to determine when various units in an incoming air raid will be detected by defenders, based on which further modules can be called into 'action'.

The NWGS, considered as a whole, should provide a wide variety of engagement assessment modules that will realistically simulate combat losses and damages when opposing forces 'engage'. The 'fineness' of the simulated engagement will depend on the one-on-one engagement modules that will combine to make force-wide engagement models. Before we go on to list various modules, let us take a note of the levels of engagement at which 'combat' can be simulated.

With respect to the modules employed, three types of games can be distinguished:

(a) System Level Games: These provide only system simulators and possibly weapons data bases to enable players to specify units rather than the parameters needed in the simulation. These are not games in the strict sense of the words but are little more than interactive simulations.

(b) Engagement Level Games: Engagement games provide a true gaming capability by providing engagement assessment modules and rudimentary game executives that enable players to specify limited scenarios involving combat between a few units and control actions as the scenario evolves. Because engagement games involve only one kind of engagement (say a sea-skimmer against a general purpose ship), their output can be much more detailed than large-scale games which use a variety of engagement assessment modules.

(c) Full-Scale Games: Full-scale games add to the engagement games a full game executive capable of tracking a number of different units, calling on a variety of different engagement assessment modules as necessary, and accepting combat control inputs from several sources.

Apart from engagement 'level' consideration, following also influence the design of any computer-assisted war game. For sake of brevity, only a mention is made of the points and a suggested spectrum for NWGS is given in Table V.

Structure of the opposition

Opponent structure

Preprogrammed games
Computer-opposed games
Freely played games

Player structure

Single player games
Multi player games

Number of sides

One-sided games
Two-sided games
Multi-sided games

As a minimum, larger scale engagement modules should be provided for

- surface warfare
- anti-air warfare
- submarine warfare
- anti-submarine warfare
- mine warfare.

Table v: Suggested Spectrum of NWGS Gaming Capabilities

| Game Type | Description | Play Options |
|---|---|---|
| System Level | Provides access to system simulators to enable examination of effects on performance of changes in parameters | None |
| Engagement Level | Small scale games that enable simulation of tactical engagements between units or small groups of homogeneous units. | Programmed - engagements proceed according to a fixed scenario with decision branches controlled by the computer.<br><br>Computer opposed - command and control for one of the forces is provided by the computer in accordance with pre-structured decision/action tests.<br><br>Free-Play - both opposing forces are under the tactical command of human players, and the scenario evolves. |
| Full-Scale Games | Large scale games involving whole forces over wide areas under the command and control of human players. | One-sided - Umpires control opposing forces and/or parts of the game scenario for player controlled forces.<br><br>Two-sided (or Multi-sided)- All forces are controlled and directed by human players. |

2-3. NWGS DATA BASES

The NWGS Data Base consists of data files containing data on capabilities and performance characteristics of platforms, weapon systems and sensors. These files will provide ready access to parameters needed by system simulators and engagement assessment modules for combat simulation. Typical characteristics of units that will be contained in these data bases are summarized in Appendix A.

In addition to providing the parameters needed by system simulators, engagement assessment modules and game executives, these data bases should be directly accessible by users who may want to use them. The data bases alone can therefore be expected to become a valuable, ready source of information needed for threat and requirements studies, exercise planning and other modelling efforts.

2-4. GAME EXECUTIVES

By a game executive is meant a computer program module which maintains the profile of the tactical situation by executing one and/or more of the following tasks:

- Movement of Forces: Game executives should be able to distinguish and track reasonable movement of a wide variety of ships, aircraft, submarines and missiles (if feasible) at rates consistent with capabilities and environmental conditions along pre-structured or player-controlled

paths. Tracking may be executed either on a unit-by-unit basis or maintained for groups of units presumed to be moving in formation.

- Geography: Game executives should be able to define and monitor play in an area of operations described at the same level of detail as standard nautical charts for the area showing : land masses and national boundaries; altitudes and water depths; and flight and movement restrictions. Over and under this area of operations the executive should, moreover, be able to track unit movements to specified altitude and subsurface limits. Location and capabilities of fixed facilities such as radar sites, shore batteries, docks, storage depots etc., can be specified for each game.

- Environmental Factors and Areas: Game Executives should be able to define and monitor the operating environment, defining such conditions as cloud cover, visibility, weather and sea state, air and water temperatures, etc., for environmental areas within the area of operations.

- Logistics: In addition to tracking motion, game executives should be able to simulate and record expenditures of ammunition fuel, and consummables and maintain current status of participating units. The logistic status can be reflected as constraints on maneuverability and operational capability of the units simulated.

In addition to above, game executives should also maintain:

- Record of elapsed time
- Record of results of engagements (a great help at the time of 'debriefing')
- Identification of critical decision points for human players.

## 2-5. COMMAND CENTRES AND COMMUNICATIONS

So far we have talked about the software requirements of the NWGS. However, for the war games to be played with realism in mind, certain physical facilities have to be provided to the game players. They are enumerated in following paragraphs.

2-5.1 Command Centres: The NWGS war gaming facility should be configured to support game play among players who operate from physically separated command centres.

Each command centre should have:

- Direct access to the NWGS computer(s) via consoles/terminals that will handle inputs of tactical directives and intelligence and provide alphanumeric and graphical displays of information available to each command.
- Flexibility for assignment as a particular platform as listed in Table II.
- A system for flexible voice and record communications accesses, so that command centres can be linked with simulated communications network (may be with preassigned priorities).
- Communication links should be routed through computer(s) so that communication degradation, jamming and delays can be realistically simulated.

- Necessary hardware such as captain's console, Navigating officer's PPI, Plotting (Hard copy) facilities, QM's wheel, Gyro displays, etc.

2-5.2 Game Umpires: To enable accurate umpiring of the game, one or more umpire positions will have to be provided which will house the game umpires. In addition to the facilities available at command centres, the umpire positions should have:

- Communication facility to monitor communications of (player) command centres to simulate intercepts and coordinate game play.
- Facility to temporarily/permanently disqualify/disable one or more command centres participating in a game.
- Facility to override tactical directives issued by one or more command centre(s). Such supersession shall however, be communicated to the concerned command centre(s).
- Facility to alter environmental conditions with/without notice to the command centres.
- Facility to start/stop the game.

In addition to the above, such facilities as a central display (hard copy as well as dynamic) and recording, replay of earlier or last played game(s), etc., will have to be made available for the NWGS.

2-6. EXTENSION TO REMOVE SITES

After the NWGS has been fully computerized (as per above framework and later modifications, if any), it will be possible to set up additional player command centres and/or data base access centres (DBAC's). To do this, a proposed site will need:

- A compatible input/display console to provide the player-computer interface.

- A high quality data communications link between the console and the NWGS computer for I/O of game information and record communications.

- Parallel voice communication links to provide access to the game voice networks and

- A separate, full time voice or record communications link with the game floor (where NWGS is installed) to coordinate game play.

The data base access centres (DBAC's) will however need only the first of the above listed facilities. The DBAC will actually be nothing more than a compatible console. But this facility will provide the DBAC user with a powerful method to have an update display/record of NWGS data bases.

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# 3. ASMD DATA BASE

The ASMD-problem requires data on Platforms, Sensors (Radars and EW Receivers) and Weapons only. Data on under-water sensors and weapons is not used. Therefore, data bases for platforms, radars, ESM receivers, weapons and guided-weapons were created and implemented.

The ASMD data bases reported here may not be data bases in the strict sense of the word (with reference to DBMS terminology). It may be appreciated that a definite level of complexity would have been introduced into the ASMD simulation problem, had the strict DBMS approach been taken to design and implement the ASMD data bases. Moreover, complete design and implementation of a data base alongwith a querry/manipulation facility constitutes a major exercise, that warrants a semester or more of group effort [KHAR 78].

## 3-1. <u>NEED FOR DATA BASE</u>

Why data base?

Following objectives have been suggested by Fry and Sebley [FRY 76]:

- To make an integrated collection of data available to a wide variety of users;
- To provide data independence - both physical and logical. A system is said to have physical data independence if the program or adhoc requests are relatively independent of the storage or access methods. Whereas logical independence is the ability to make logical change to the data base without significantly affecting the programs which access it;

- To allow centralized control of the data base, which is necessary for efficient data administration; and

- To insure retention of privacy through security measures within the system.

The ASMD data base meets the first objective only. However, the ASMD data base should be considered as a starting point for developing the NWGS data base.

Sections 3-2 to 3-4 describe the ASMD data bases with reference to the following:

(a) Identification of parameters needed to describe the platform/sensor/weapon.

(b) Description of the parameter(s) where necessary.

## 3-2. DATA BASE FOR PLATFORMS

For a reasonable description of a platform (restricted to mean a ship in ASMD context), the parameters listed in Appendix A1 reproduced at Table VI for convenience were considered. A description of parameters is given below serially:

(1) Ship Basic Classification: A code number corresponding to the role of the ship can be assigned to this parameter as per available directory. For example:

| Code Number | Description |
|---|---|
| 1 | Anti-aircraft role |
| 2 | Anti-submarine role |
| 3 | Surface combat ship |
| 4 | Fast patrol boat |
| 5 | General purpose ship |
| ⋮ | ⋮ |

TABLE VI

( ASMD DATA BASE )

## PLATFORM DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNITS |
|---|---|---|
| 1 | Ship Basic Classification | Code number |
| 2 | Length | Meters |
| 3 | Beam | Meters |
| 4 | Height (averaged with superstructures) | Meters |
| 5 | Draught | Meters |
| 6 | Maximum Speed | Knots |
| 7 | Cruising Speed | Knots |
| 8 | Endurance | Nautical Miles |
| 9 | Radius of Turn (At maximum speed ) | Meters |
| 10 | Carries Helecopter ? | Code number |
| 11 | Name or Ship I.D. | Code number |
| 12 | Maximum Wheel that can be applied | Degrees |
| 13 | Ship's RCS: BOWON | Meters**2 |
| 14 | Ship's RCS: BEAMON | Meters**2 |
| 15 | Future extension | - |

(2) to (5) These serials represent the size information of the ship.

(6) Maximum Speed: Is the maximum speed that the ship can do. In peace time, ships seldom do maximum speed.

(7) Cruising Speed: Is the economical speed for the ship. During a passage, cruising speed is maintained unless told otherwise.

(8) Endurance: Self explanatory.

(9) Maximum Radius of Turn: Represents the minimum radius to turn the ship by $360^{\circ}$ at a specified speed.

(10) Carries Helicopter?: A code number representing the type of aircraft carried on board can be assigned as per available directory. For example:

| Code No. | Description |
|---|---|
| 1 | No |
| 2 | Yes, Helo/VTOL |
| 3 | Yes, Jet aircraft |
| 4 | Yes, 2 and 3 both |
| ⋮ | ⋮ |

(11) Name or Ship I.D.: A code number representing the type and class of ship can be assigned to this parameter as per the available directory. For example:

| Code No. | Description |
|---|---|
| 1 | Aircraft carrier |
| 2 | Cruiser |
| 3 | Missile cruiser |
| 4 | Frigate |
| 5 | Corvette |
| 6 | FPB's |
| 7 | Hydrofoil ship |
| ⋮ | ⋮ |

(12) Maximum Wheel: Is the maximum angle of deflection that can be applied to the ship's rudder.

(13) and (14) Provide information on ship's RCS. See Figure 1 for a description of BOWON and BEAMON directions.

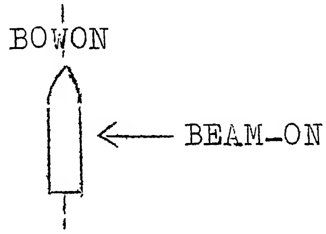



Fig. 1: Illustration of BOWON and BEAM-ON Directions.

(15) For future expansion. (For classified parameters like ship's noise figure, number of propellers, call sign etc.

3-3. DATA BASE FOR SENSORS

Two separate data bases : one for radar and the other for ESM receivers are considered here.

3-3.1 Data Base for Radars: The parameters that have been considered for description of a Radar (including Radars mounted on the missile) are listed at Appendix A2 (reproduced at Table VII for convenience). A serial description of all the parameters follows:

(1) Radar Type: A code number representing the the type of radar. Example:

| Code Number | Description |
|---|---|
| 1 | Surface search and Navigation Radar |
| 2 | Medium-air/long-surface warning radar |
| 3 | Early air warning |
| 4 | Fire control |
| 5 | Mounted on missile |

TABLE VII

( ASMD DATA BASE )

RADAR DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNIT |
|---|---|---|
| 1 | Radar Type | Code number |
| 2 | Frequency Band | Code number |
| 3 | Frequency : upper limit | MHz |
| 4 | Frequency : lower limit | MHz |
| 5 | Typical Ranges (Air/Su) | Nautical Miles |
| 6 | Antenna Rotation Rate | RPM |
| 7 | Peak Elec Power | KW |
| 8 | Receiver Sensitivity | dBm |
| 9 | Antenna Gain | dB |
| 10 | Acquire variable | Logical |
| 11 | ECCM Features (I) | Code number |
| 12 | ECCM Features (II) | Code number |
| 13 | Receiver Gain | dB |
| 14-15 | Future expansion | - |

(2) Frequency Band: Code number represents the frequency band of operation of the radar. Example:

| Code Number | Description |
|---|---|
| 1 | L Band |
| 2 | S Band |
| 3 | X Band |
| ⋮ | ⋮ |

(3) and (4) Self-explanatory.

(5) Typical Range Coverage: Provision exists to enter either/or both the air and/or surface range information.

(6) Antenna Rotation Rate: In case the radar has more than one rotation rate, it can be entered too.

(7), (8) and (9) Self-explanatory.

(10) Acquire Variable: Set to 1 if the radar has 'acquired' a target. Zero otherwise.

(11) and (12) Classified information.

(13) Self-explanatory.

(14) and (15) for future extension. (For parameters like side lobe level, PRF, vertical beam width, horizontal beamwidth etc.)

3-3.2 <u>Data Base for ESM Receivers</u>: The parameters that have been used to describe ESM Receivers are listed at Appendix A3. For the sake of convenience, it has been reproduced at Table VIII. A serial description of parameters follows:

# TABLE VIII

( ASMD DATA BASE )

## ESM RECEIVER DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNIT |
|---|---|---|
| 1 | Type of Receiver | Code number |
| 2 | Frequency | Code number |
| 3 | Upper Frequency Limit | MHz |
| 4 | Lower Frequency Limit | MHz |
| 5 | Receiver Sensitivity | dBm |
| 6 | Receiver Antenna Gain | dB |
| 7-10 | Future expansion | - |

(1) Type of ESM Receiver: A code number indicating the type of receiver. Example:

| Code Number | Description |
|---|---|
| 1 | Detection RX |
| 2 | Intercept Rx |
| ⋮ | ⋮ |

(2), (3) and (4) Frequency of operation: As in Radar.

(5) and (6) Self-explanatory.

(7) to (10) for future extension.

3-4. DATA BASE FOR WEAPONS

Since guided weapons require more parameters for description, two separate data bases were created. One for unguided weapons (including chaff) and the other for guided weapons. However, guided weapons data base should be viewed as an extension to weapons data base.

3-4.1 Data Base for Weapons: The parameters needed to describe weapons are listed at Appendix A5. However, for ease of reference, it is reproduced at Table IX. Serial description of parameters used follows:

(1) Type of Weapon: A code number indicating the weapon type. Example:

| Code Number | Description |
|---|---|
| 1 | Guided |
| 2 | Unguided, gun |
| 3 | Semi-guided |
| 4 | Unguided, rocket |
| ⋮ | ⋮ |

# TABLE IX

( ASMD DATA BASE )

## WEAPONS DATA BASE CHARACTERISTICS

| SL | PARAMETERS | UNITS |
|---|---|---|
| 1 | Type of Weapon | Code number |
| 2 | Weapon Class | Code number |
| 3 | Minimum Intercept Range | Kms |
| 4 | Maximum Intercept Range | Kms |
| 5 | Type of Warhead | Code number |
| 6 | Burst Radius or Rated RCS after Bloom Time (CHAFF) | Meters or Meters**2 |
| 7 | Rate of Fire | RPM |
| 8 | Hit/Kill Probability (if 1,indicates CHAFF data) | % |
| 9 | Barrel/Tube Diameter or Deoployment Time (CHAFF) | mm or Seconds |
| 10 | Row Value in Guided Weapons Data base (if applicable) or Saturation Time (CHAFF) | Integer or Seconds |
| 11 | Row value in Radar data base (if applicable) for data on Guided Missile's radar | Integer |
| 12-15 | Future expansion | - |

(2) Class of Weapon: A code number indicating the weapon class. Example:

| Code Number | Description |
|---|---|
| 1 | Anti-aircraft |
| 2 | Anti-surface (anti-ship) |
| 3 | Anti-submarine |
| 4 | A/A and A/Su both |
| 5 | EW |
| ⋮ | ⋮ |

(3) and (4) Range: Effective minimum and maximum range of the weapon.

(5) Warhead: A code number indicating type of warhead

| Code Number | Description |
|---|---|
| 1 | TNT |
| 2 | Nuclear |
| 3 | Aluminium Foils (CHAFF) |
| ⋮ | ⋮ |

(6) to (10) Self-explanatory.

(11) Row value of guided missile rader in radar data base (if applicable).

(12) to (15) For future expansion.

In case of CHAFFs, serial (8) contains '1'. Serials (6), (9) and (10) are then interpreted as:

(6) Rated RCS of chaff after bloom time.

(9) Deployment time: Time taken for the chaff flight and blooming.

(10) Saturation time: Time after which chaff disintegrates itself and no longer remains a strong reflector of electromagnetic radiation.

3-4.2 Data Base for Guided Weapons: List of parameters describing guided weapons (other than those used in the guidded weapons data base) is given at Appendix A6. It is, however, reproduced at Table X for ease of reference. Serial description of parameters follows:

(1) Row value in weapons data base: For linking purposes.

(2) RCS (X band) of the weapon.

(3) Self explanatory.

(4) Guidance: A code number indicating type of guidance used. Example:

| Code Number | Description |
|---|---|
| 1 | Command guidance |
| 2 | Inertial guidance |
| 3 | Beam rider |
| 4 | Electro-optical |
| 5 | Inertial + Radio altimeter |
| 6 | Active rader seeker |
| 7 | Monopulse radar |
| 8 | IR guidance |
| ⋮ | ⋮ |

(5) Frequency: If applicable, indicates the frequency of command guidance signal.

(6) Minimum range from launcher where cruise mode commences.

(7) Maximum range from launcher where cruise mode terminates.

(8) Self-explanatory.

(9) Maximum manoeuvring allowed (in cruise mode).

(10) As in (4), but here it is the attack mode.

# TABLE X

## ( ASMD DATA BASE )

### GUIDED WEAPONS DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNITS |
|---|---|---|
| 1 | Row Value in Weapons Data Base | Integer |
| 2 | Missile RCS | Meters**2 |
| 3 | Missile Speed | (MACH no. *100) |
| 4 | Guidance (Cruise Mode) | Code number |
| 5 | Frequency(Cruise Mode) | MHz |
| 6 | Lower Range from Launcher (Cruise Mode) | Km |
| 7 | Upper Range from Launcher (Cruise Mode) | Km |
| 8 | Altitude of Flight (Cruise Mode) | Meters |
| 9 | Maximum Maneuvouring Allowed (Cruise Mode) | Degrees |
| 10 | Guidance (Attack Mode) | Code number |
| 11 | Frequency (Attack Mode) | MHz or Band |
| 12 | Maximum Range from Target when Search Begins (Attack Mode) | Km |
| 13 | Maximum Maeuvouring Allowed (Attack Mode) | Degrees |
| 14 | Altitude of Flight (Attack Mode) | Meters |
| 15 | Maximum Load Factor | *g |
| 16 | ECCM Features | Code number |
| 17-20 | Future expansion | - |

(11) Frequency: Of the active seeker, if present.

(12) Maximum range from target at which active search for target commences.

(13) Maximum manoeuvrability allowed for the missile.

(14) Self-explanatory.

(15) Maximum Load factor: Useful in determining missile's minimum radius of turn.

(16) ECCM feature, if applicable to missile's radar.

(17) to (20) For further extension.

## 3-5. DATA BASE CREATION/IMPLEMENTATION

Having studied the characterstics of the ASMD data bases, we will now take up the question of data base implementation. Section 3-5.1 deals with the question of the choice of data structure and Section 3-5.2 gives implem ntation details.

3-5.1 Choice of Data Structure: If we attempt to give a visual representation to the ASMD data base studied earlier, it will look like Figure 2. It does not take long to associate the structure of Figure 2 with that of a linked list structure as suggested by Horowitz and Sahni [HORO 76].

During initial stage of this work, effort was made to implement the linked-list type of structure for ASMD data base. However, we should not forget that for the ASMD problem, we needed to use only one platform, one or

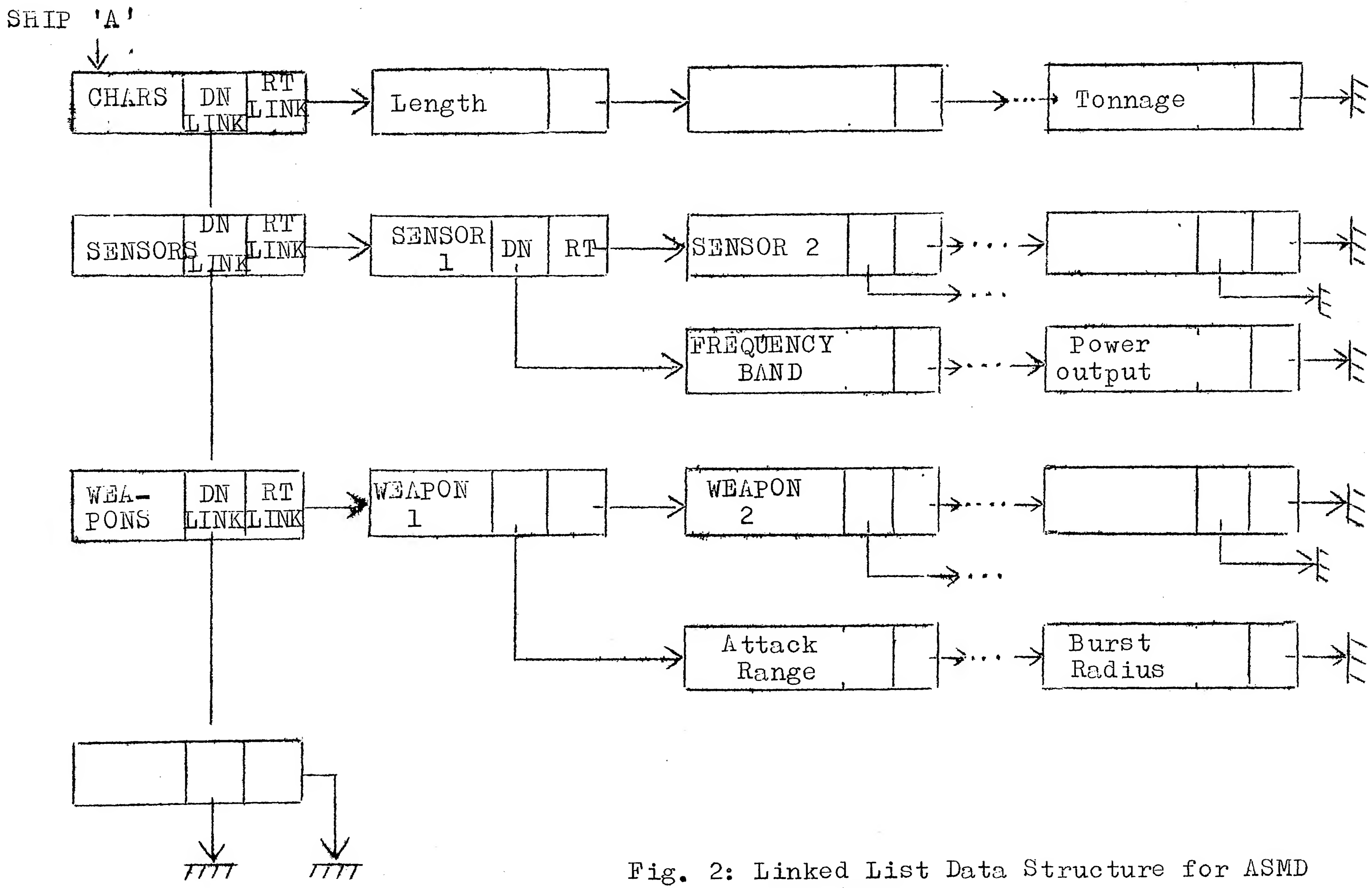



Fig. 2: Linked List Data Structure for ASMD Data Base

more radars (say 3), one or more weapons (say 2) and one or more ESM receivers (say 1), and hence the points of concern were:

(i) Simple structure (not complex)
(ii) Straightforward access mechanism.

The linked list data structure was found unsuitable because of following reasons. However, the linked list structure provides good facilities for addition/deletion of entries in the data base.

(i) It was too complex a data structure.
(ii) It involved lengthy access mechanisms which would have added heavy overheads on overall gaming system performance.

As a compromise, simple and straightforward 'array' structure was chosen for implementing the ASMD data base. Though a small amount of sparsing was caused due to the provision for future extensions in the data bases, yet the overall gains favoured the array structure.

3-5.2 Data Base Implementation: Each data-base (Radar, Weapons etc.) was implemented as an m x n matrix as shown in Figure 3. Rows 1 to m correspond to the number of entries in the data base, whereas columns 1 to n represent the parameters of that data base. Since the language used was FORTRAN 10 (FORTRAN IV with extensions as implemented on DECsystem 1090) integer matrices were used to save total memory used.

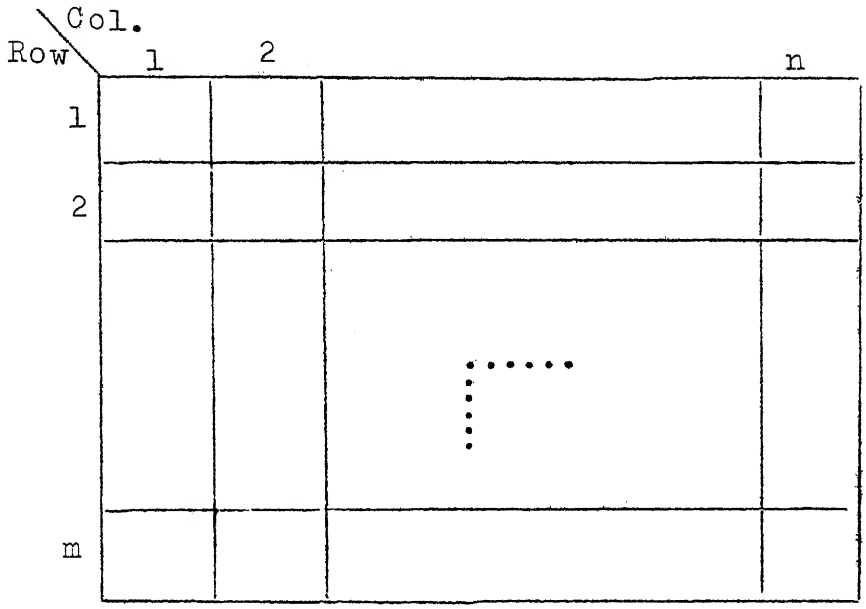



Fig. 3: Data Structure Used.

File handling capabilities of FORTRAN 10 were used to create the data base on random access files. Random access files facilitate access of any record in a random fashion at the time of game scenario definition (see Section 5-3). Suitable codes were used to represent 'not applicable' and 'future extension' entries in the data base. For details regarding creation of random access files refer DEC 10 manuals [DEC 77].

# 4. ASMD SIMULATION MODELS(s)

In describing models used in ASMD simulation, direct references are made to the simulation program (listed at Appendix B). Flowcharts are provided wherever found necessary.

## 4-1. THE SHIP

As stated in the assumptions (Section 1-4), ship has been simulated as a point target. However, size of the ship has also been considered (see Section 4-3.5).

Following sections describe various routines that describe the ship's actions.

4-1.1 Motion: Ship's motion has been simulated as a straight line within every time step. The acceleration, if any, has been assumed to be zero. This does not add any significant error since the attacking weapon for the present problem i.e., the missile moves at a 1:30 speed ratio.

4-1.2 Update Position: Updating of ship's position every time step (DELT) is done by subroutine UPDATE. For constant speed motion, the following equations have been used:

$$XS = XS + VS * \mathrm{Cos}(DIRS) * DELT$$
$$YS = YS + VS * \mathrm{Sin}(DIRS) * DELT$$

In addition, effect of the surface wind has also been simulated by subroutine UPDATE, as described in Section 5-7.

4-1.3 Evasive Action: Evasive action (against an attacking missile) implies:

(i) Course alteration (to change direction of motion) in such a fashion so as to present minimum target profile to the missile. The choice to turn PORT/STARBOARD (left/right) is governed by the shortest route consideration, as depicted in Fig. 5.

(ii) Increase speed to maximum speed once evasive action has been completed.

Subroutine COURSE simulates the evasive action by the ship. Input parameter WHEEL represents the angular displacement in degrees that is applicable to the ship and is based on:

(i) Maximum radius of turn (at maximum speed)

(ii) Current speed of operation.

The subroutine essentially modifies DIRS based on the 'evasion' logic given as a flowchart in Fig. 6. Output parameter JEVASE is set to 1, when evasive action has been completed.

4-1.4 RCS (Radar Cross Section) of Ship: Subroutine SHRCS computes ship's RCS based on the aspect presented to the missile and the data from ship's data base. The equation used is:

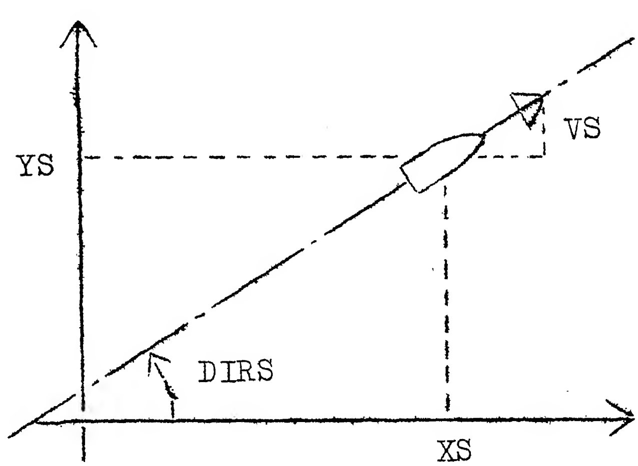



Fig. 4: Ship's Motion

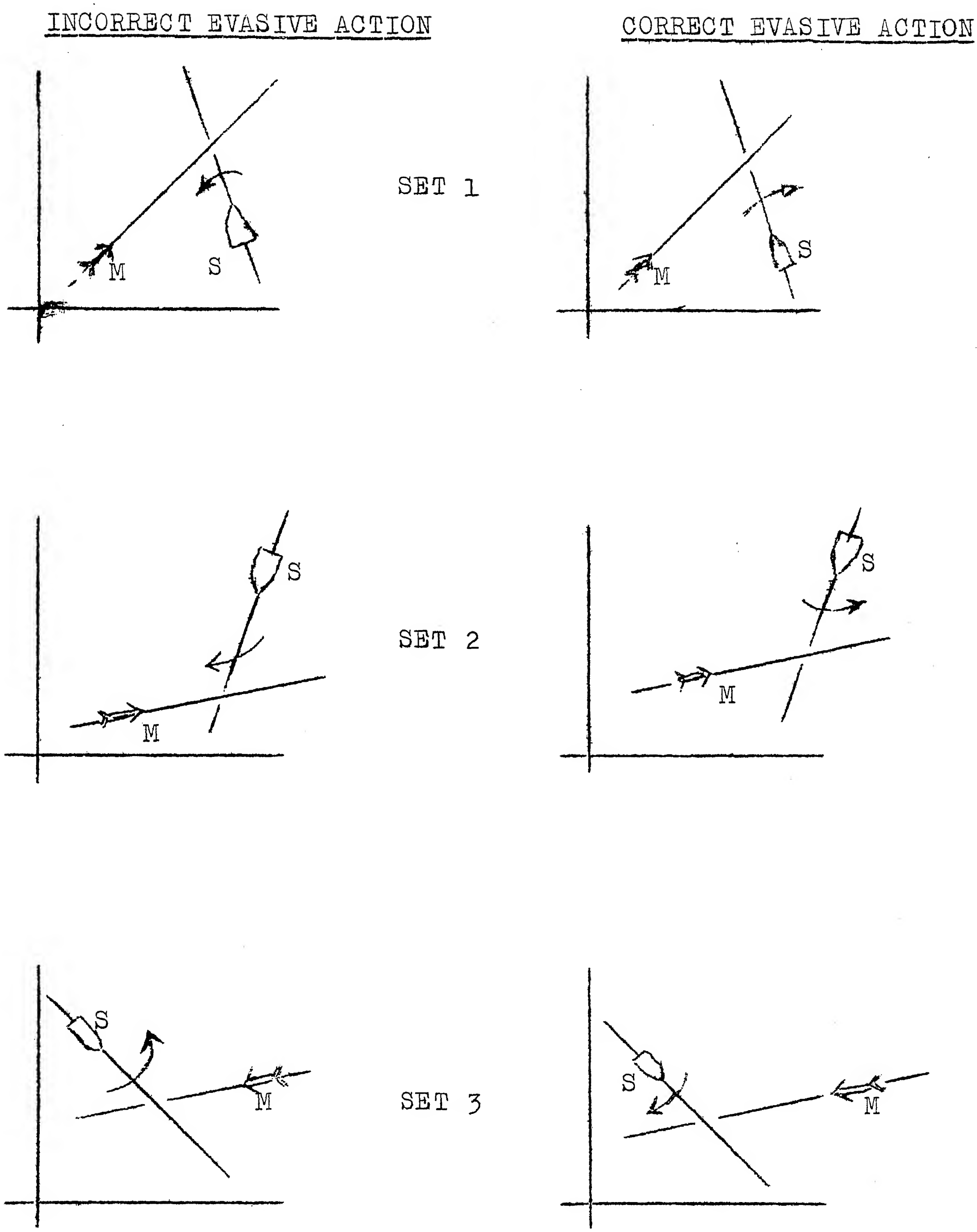



Fig. 5: Evasive Action by Ship

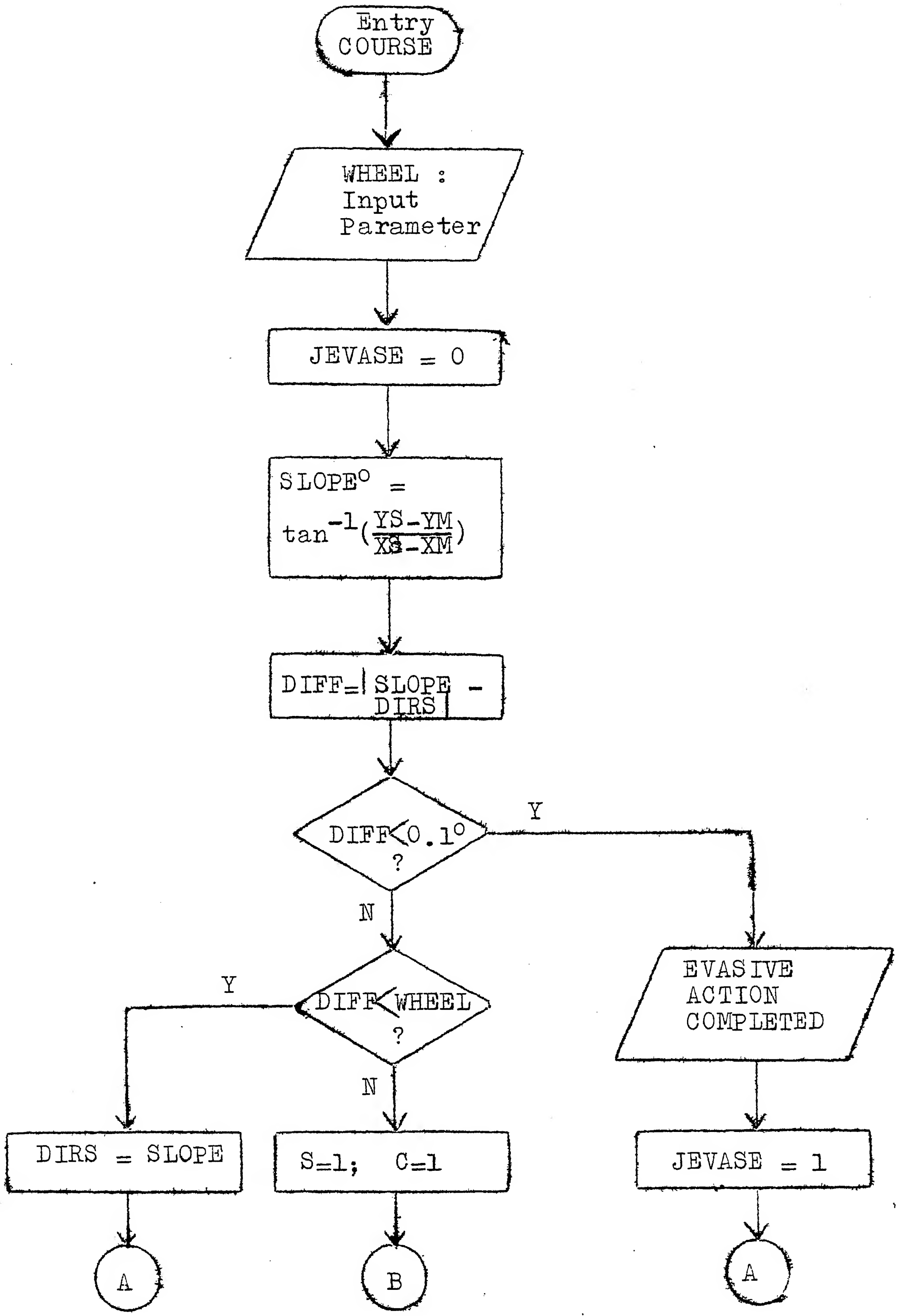



Fig. 6: Evasion Logic : Flowchart (continued)

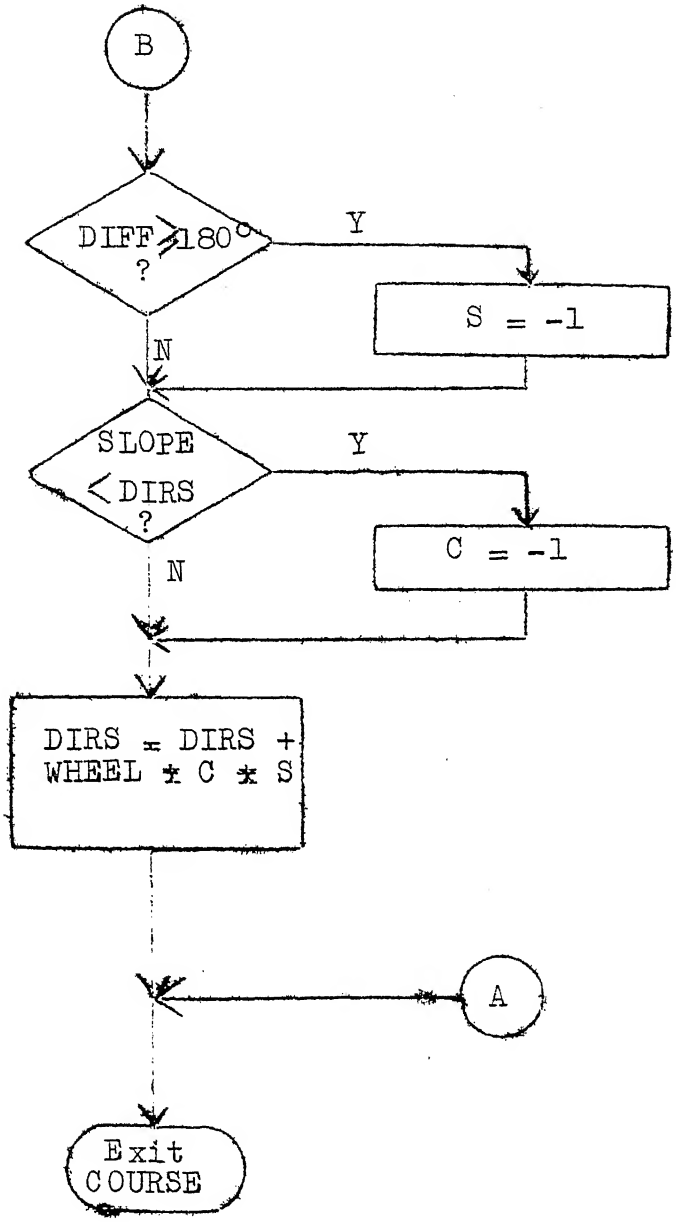



Fig. 6: Evasion Logic : Flowchart

$$SRCS = BOWON + BEAMON * ABS(\sin(DIFF))$$

WHERE :

BOWON = Ship's RCS when looking from BOW-ON direction (see Figure 7).

BEAMON = Ship's RCS when looking from BEAMON direction.

DIFF = (DIRS-DIRM) mod-360°.

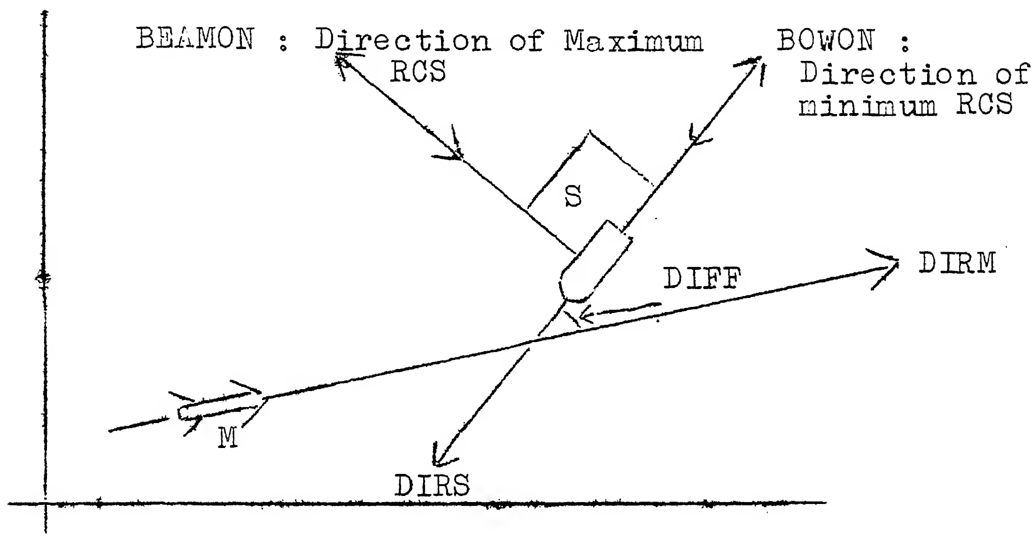



Fig. 7: Ship's RCS

## 4-2. THE MISSILE

The surface skimmer missile has been simulated as a point target. The sea-skimmers have three phases of flight trajectory irrespective of the platform from which launched, as shown in Figure 8. We have not considered the launch phase since the present ASMD problem assumes that an attacking missile is approaching. And, therefore, it is

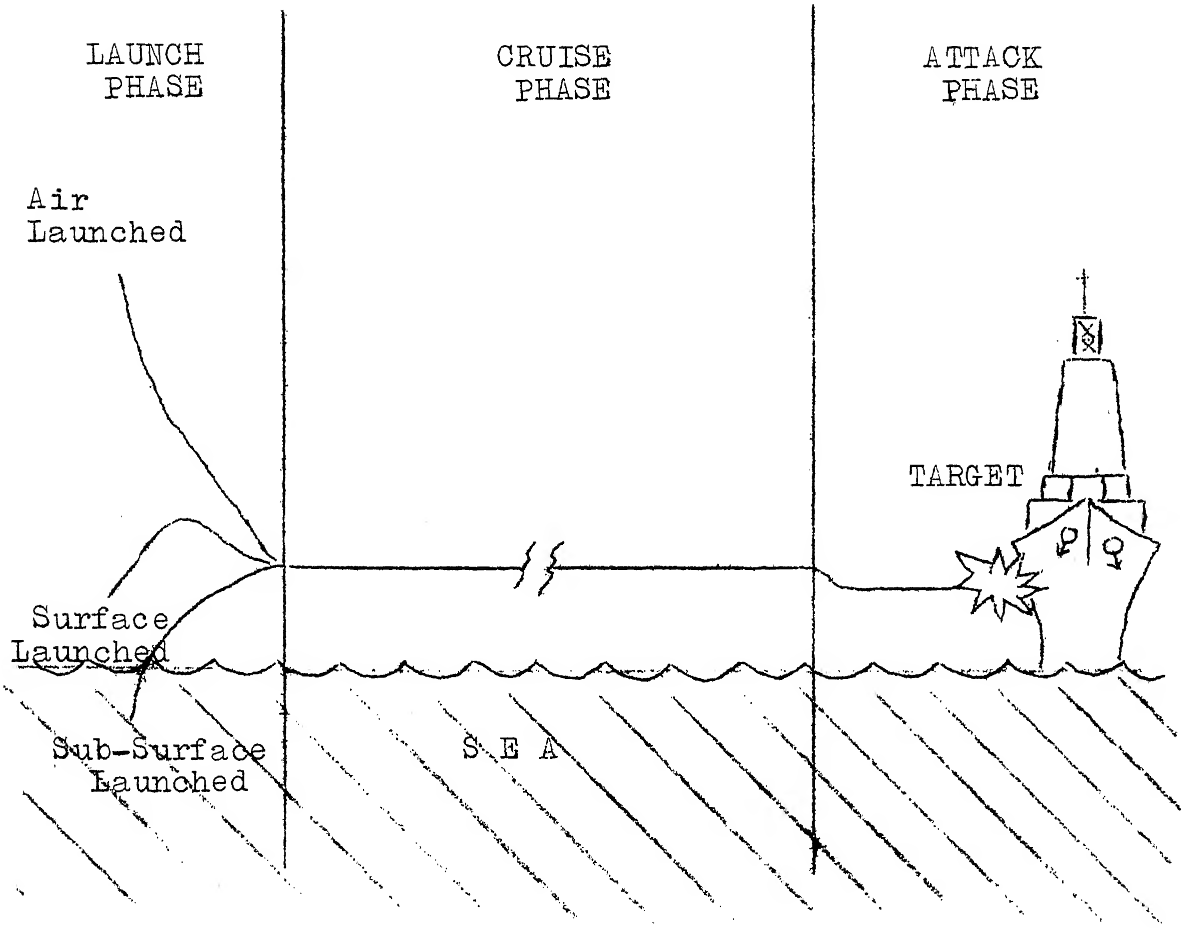



Fig. 8: Surface-Skimmer's Flight Trajectory

the portion of cruise phase and the attack phase that have been simulated. Once again, the minor difference between the altitudes of cruise and attack phase is ignored to maintain the 2D model.

4-2.1 Cruise and Attack Phase: Missile path during each time-step is assumed as a straight line. Subroutine UPDATE computes the positional coordinates XM, YM using missile velocity VM and missile course DIRM as follows:

XM = XM + VM * Cos(DIRM) * DELT
YM = YM + VM * Sin(DIRM) * DELT

Alteration in missile position due to surface wind is also considered in UPDATE.

4-2.2 Guidance: Since both types of guidance mechanisms (command guidance and inertial guidance) are available on present day-surface-skimmers for their cruise phase flight, both have been simulated in the subroutine GIDNCE.

Flag MAUTO is set to 1 if missile commander desires inertial guidance and to 0 if he prefers command guidance. This flag causes different logic paths to be followed in the calling sequence of subroutines MISMOD and GIDNCE.

In command guidance mode, the next missile course is supplied by the game player subject to maximum manoeuvring allowed (as per missile data). Whereas during inertial guidance, the missile maintains its own path by calling the subroutine MISMOD.

4-2.3 Search and Lock-on: Considering a surface-skimmer with active seeker head, subroutine MISRCH simulates the target search by missile. Once the missile has locked on to the target, MISRCH is no more called. Missile-search-zone is shown in Figure 9. The logic followed in searching the target is shown in Figure 10. (A radar detection model could also be considered here, as outlined in Section 5-1.)

The flag TLOCK is set to 1 once the missile locks on to the target i.e., when the target lies within the missile search zone.

4-2.4 Course Modification: Subroutine MISMOD computes the next course-to-steer for the missile. This routine is called when either of the following is satisfied:

(i) Missile is locked on to the target, or
(ii) Inertial guidance is on.

The logic followed in computing the next course is shown in Figure 11 as a flowchart.

4-2.5 Kill Distance: In order to consider the physical size of point-targets, certain kill-zone (KDIST) was defined for the missile. Following factors influenced the choice of a formula to assign a suitable value to KDIST:

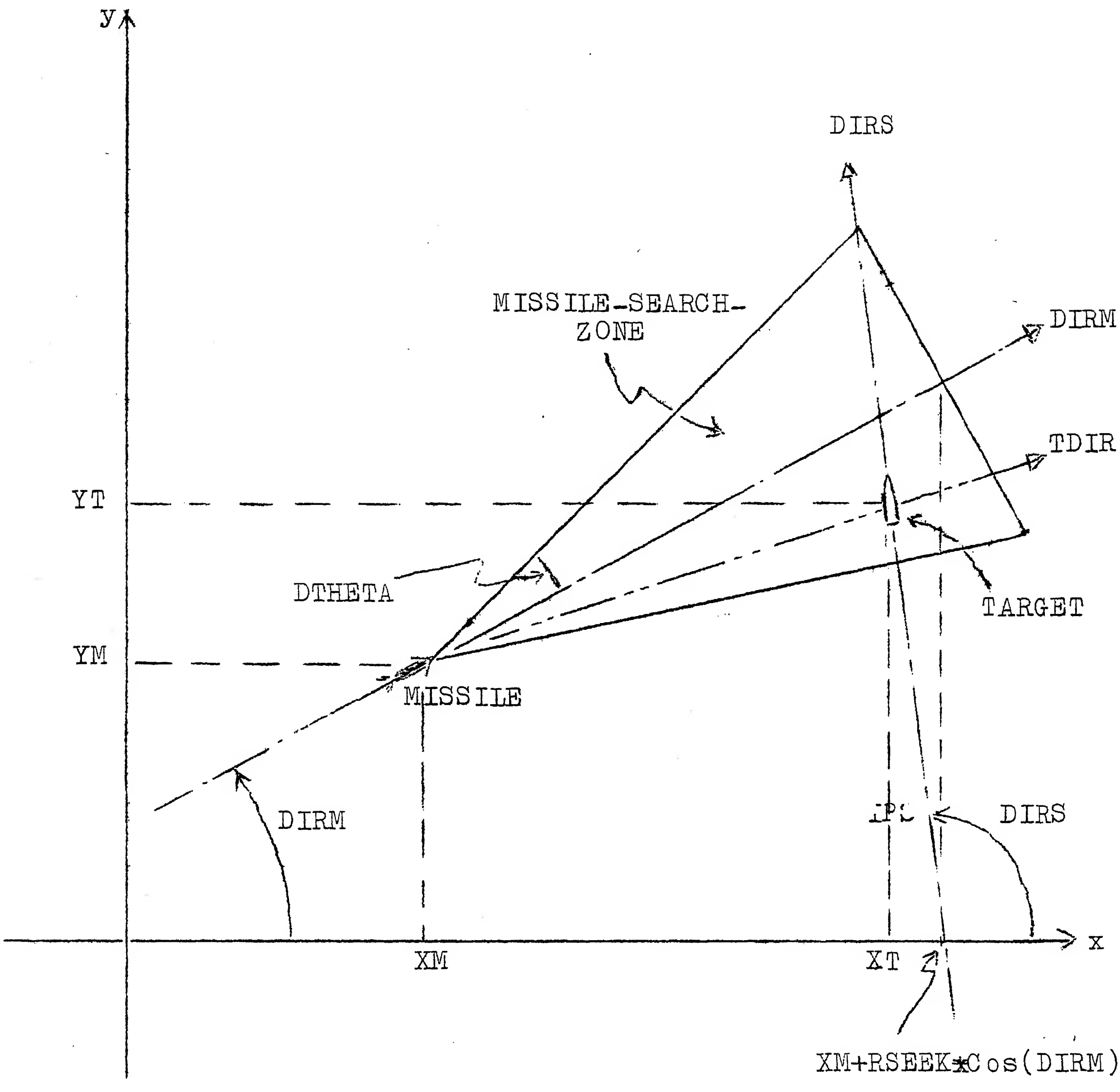



Fig. 9: Missile Search Zone

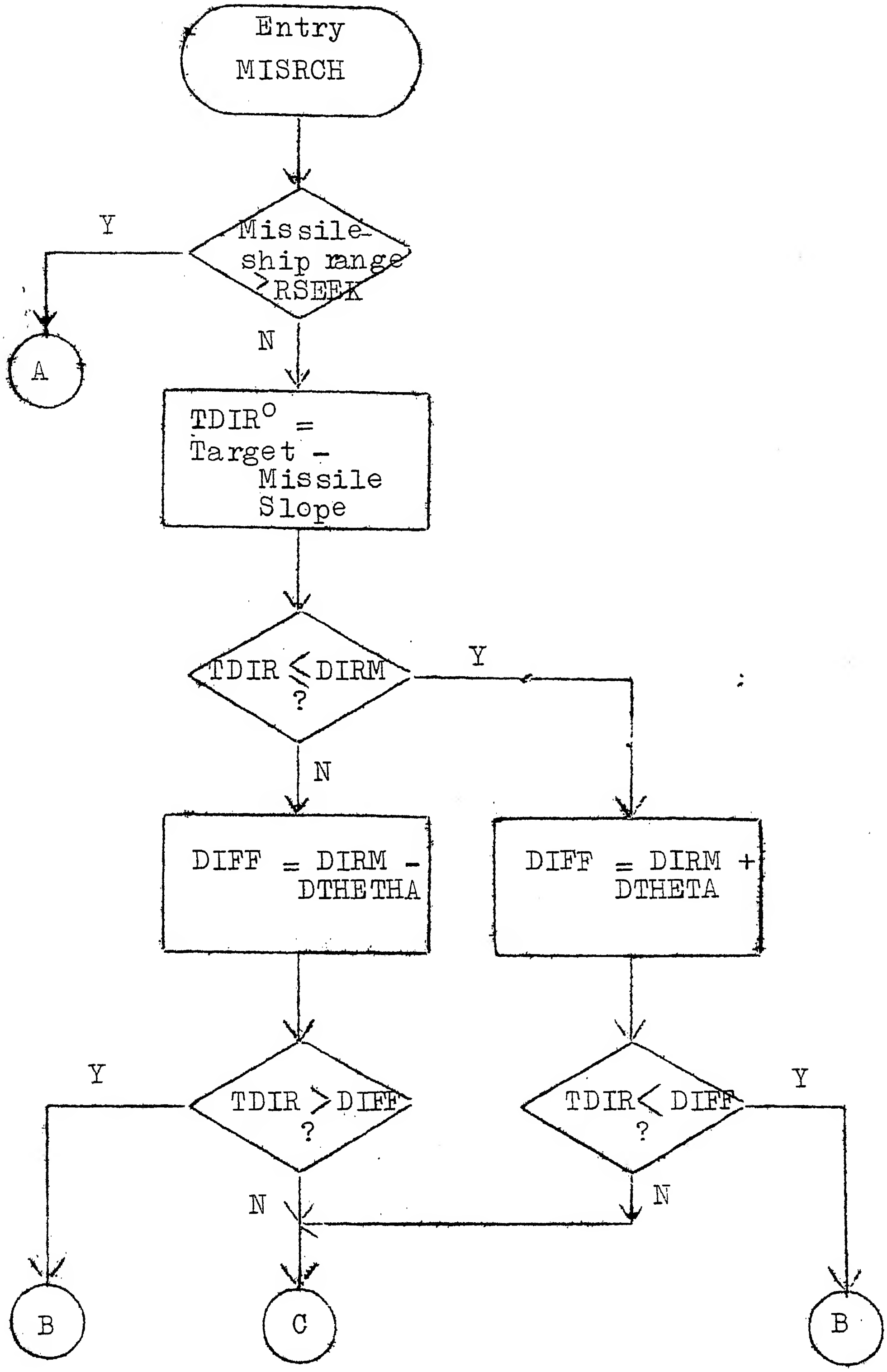



Fig. 10: Target Search by Missile (continued)

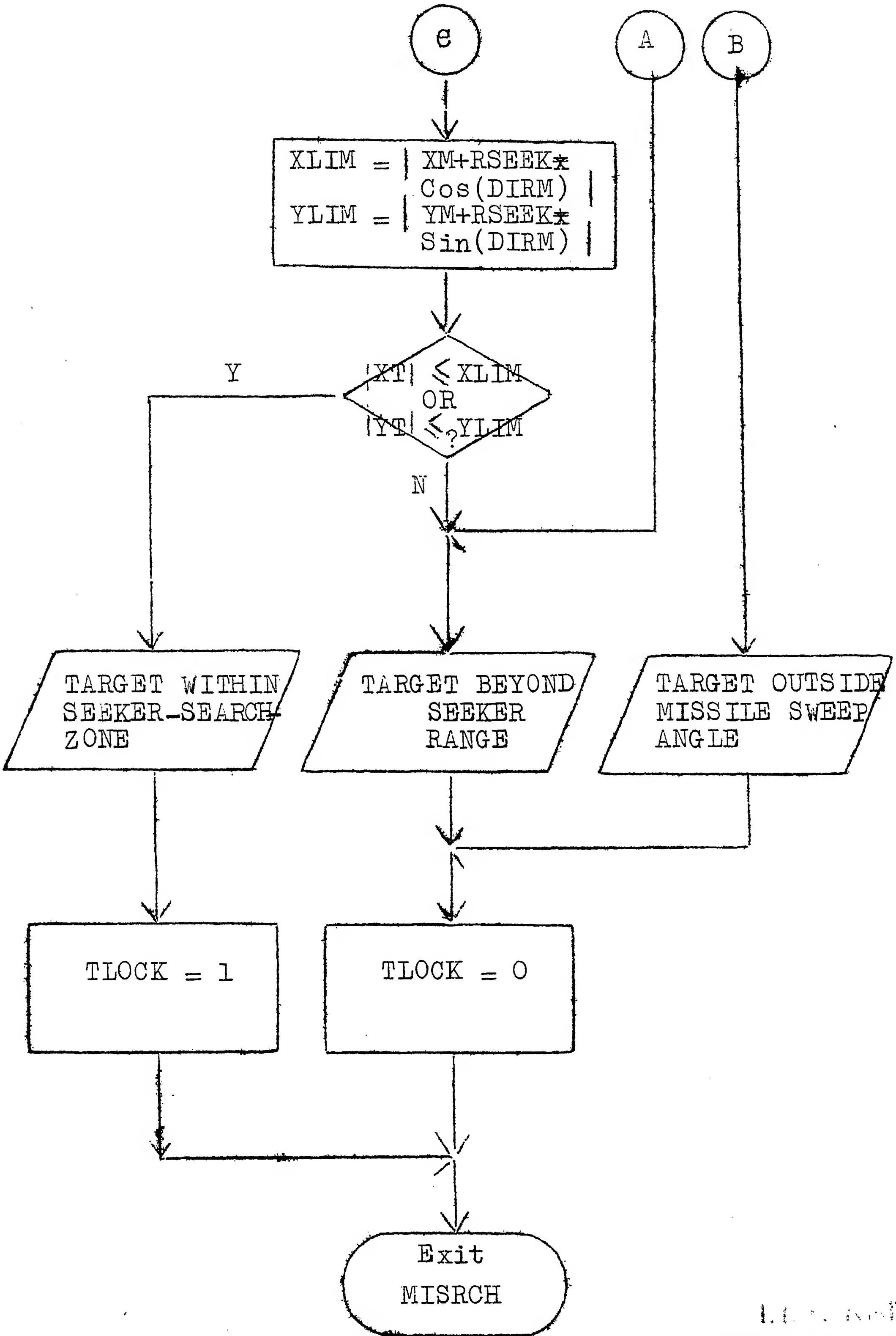



Fig. 10: Target Search by Missile

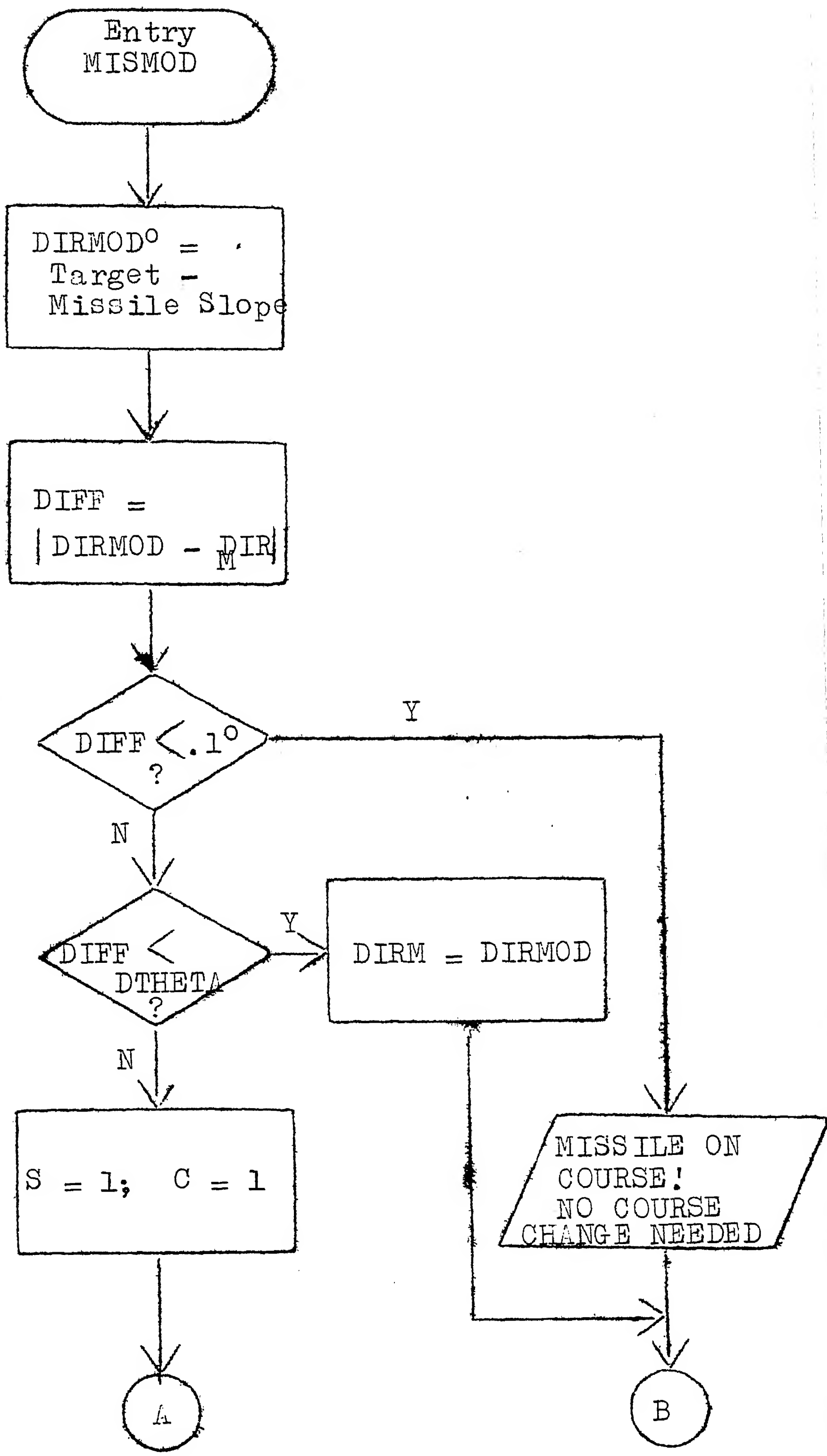



Fig. 11: Missile Course Modification : Flowchart
(continued)

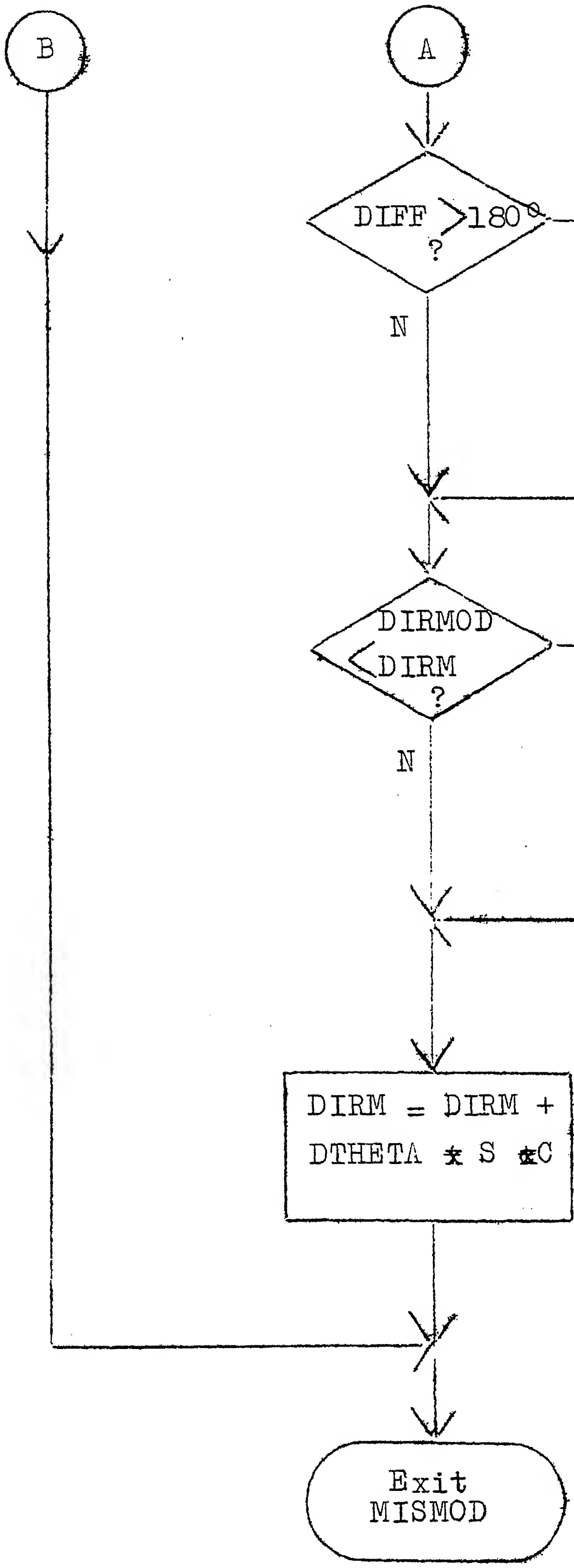



Figure 11: Missile Course Modification : Flowchart

(i) Frigate length is 100 meters approximately. Therefore, KDIST should not be less than 100 meters.

(ii) KDIST should be of the order of the distance covered by the missile in one time-step.

Therefore, the following relation was used to define KDIST:

$$KDIST = VM * DELT$$

Since VM is of the order of 1000 km/hr (.93 Mach or more) for surface-skimmers, KDIST gets a value of approximately 300 meters for a one second time step, which satisfies both the requirements.

4-3. <u>RADARS AND ESM RECEIVERS</u>

Radars and ESM-Receivers have been simulated as the on-board sensors for the ship for detecting surface objects (possible targets). Though it is well known that conventional radars may not be able to indicate the presence of an approaching surface-skimmer, yet radar detection was modelled and simulated, because radar is the prime sensor on board any ship. The ESM receivers, however, indicate radiation from targets as small as a sea-skimmer (.1m$^2$) owing to their high sensitivity. And this fact is used in game decision making.

4-3.1 <u>Detection : Active and Passive:</u> Subroutine RETECT simulates the detection by radars and/or ESM receivers.

In case of Active mode, the radars are allowed to transmit electromagnetic energy. Use of classical radar

equation [EUST 70] has been made to compute the received power at the radar receiver as shown in Figure 12. The range equation is given below:

$$P_R = \frac{P_T \times G_T^2 \times \delta^2 \times \sigma}{(4\pi)^3 \times R^4}$$

In Passive mode of detection, ESM receivers are used. The equation then becomes:

$$P_R = \frac{P_T \times G_T \times \delta^2 \times G_R}{(4\pi)^3 \times R^2}$$

where,

$P_R$ = Power received at the receiver

$P_T$ = Transmitted power (in case of Passive, = missile radar transmitted power)

$G_T$ = Transmitter antenna gain (For Passive, = missile gain).

$G_R$ = Receiver (ESM) antenna gain

$\delta$ = Wavelength of operation

$R$ = Sensor-target distance

$\sigma$ = RCS of the target

Flag DETECT is set to 1 if target is detected and to 0, otherwise. Acquire variable in the radar is set accordingly.

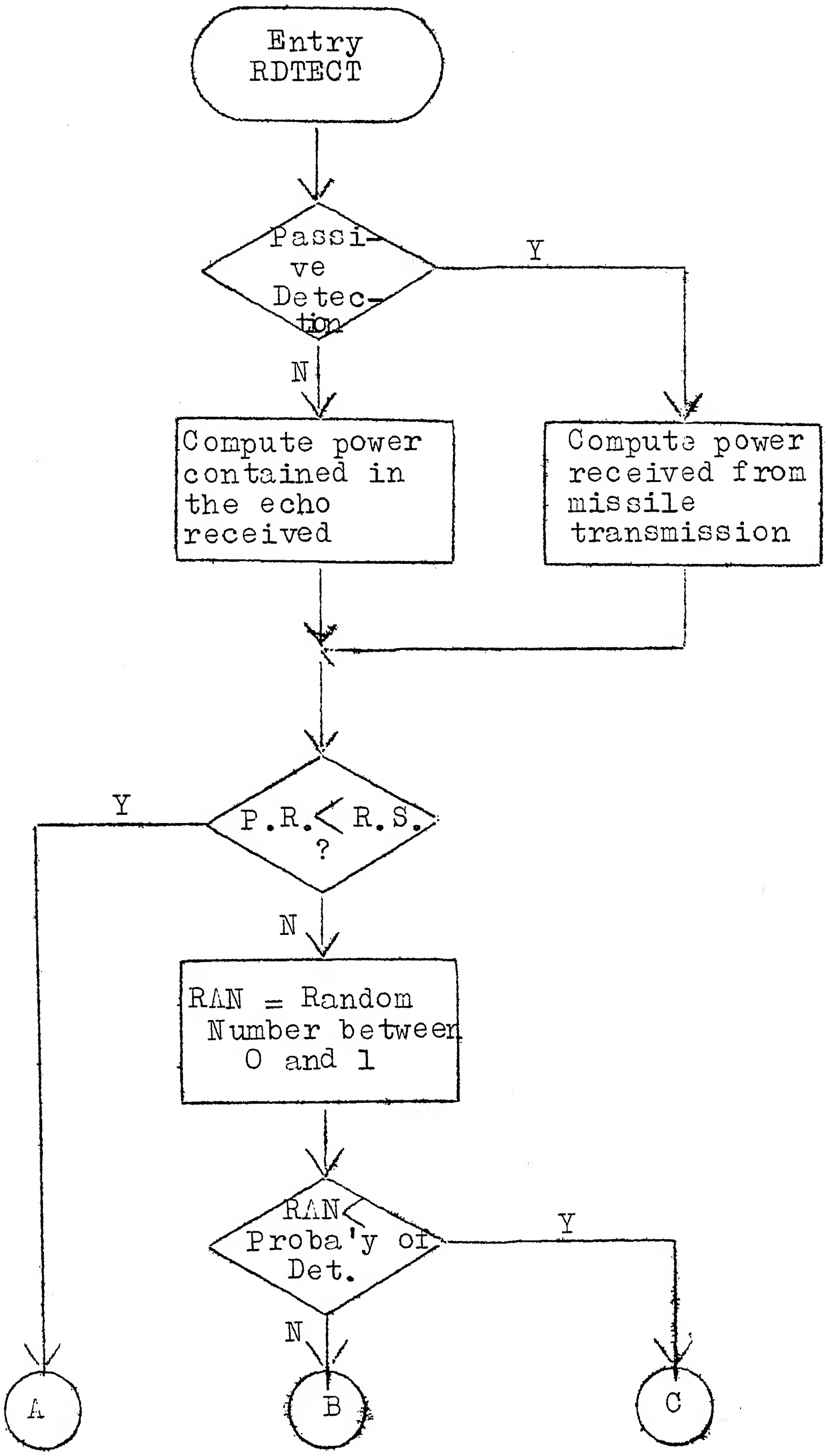



Fig. 12: Detection Logic (continued)

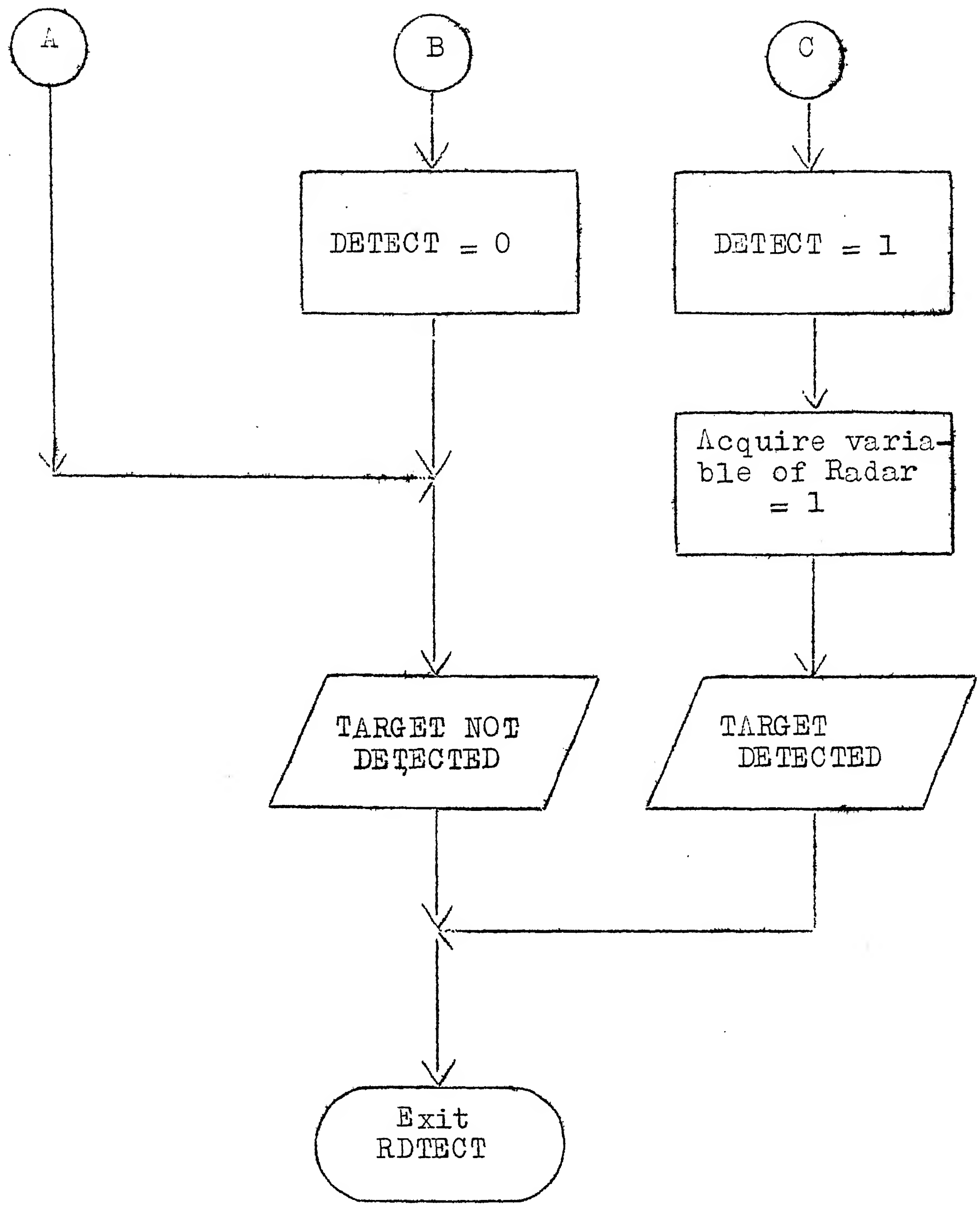



Figure 12: Detection Logic

4-3.2 Probability of Detection: To take into account factors like sea-clutter interfenrece, weather condition, operational state of the radar etc., a variable called THRESH is defined. THRESH acts as a measure of the probability of detection.

THRESH is assigned a value between 0 and 1 by the game player. The logic of using THRESH is shown in Figure 12.

4-3.3 Antenna Rotation Rate: On board radar antennas have a rotation rate of 6 to 20 rpm, which means that a particular target will be indicated every 3 to 10 seconds, depending on the antenna rotation rate. To provide realistic radar simulation, provision has been made to call the routine RDTECT for a radar only when necessary time has elapsed for it to complete one revolution.

4-3.4 Radar Silence: Radar silence implies no electromagnetic radiation by the platform. That is, for the ship, none of the on board radars/other transmitters are allowed to operate. Ship enters a total passive phase and 'listens' for any radiation from the enemy.

Flag JSILEN is set to 1 if radar silence is in force and to 0, otherwise. JSILEN affects the calls made to subroutine RDTECT.

-

# 5. ASMD SIMULATION MODELS(2)

Having discussed the platform, missile and sensors simulation models used in playing the ASMD game, we now consider the chaff, scenario definition, combat time, game tactics, wind effect and game terminating condition models.

## 5-1. THE CHAFF

As outlined in Section 1-2, the importance of electronic warfare can not be undermined. Though an old EW weapon, yet chaff was chosen in ASMD simulation reasons for which have been brought out earlier. When using chaff, two aspects need careful analysis. One, where to deploy and the other, when to fire. Following sections describe chaff simulation.

5-1.1 Deployment: In keeping with our basic assumption of point-targets, chaff too has been simulated as a point target. However, its size is considered while computing its RCS.

To compute the coordinates where chaff is to be deployed, simple coordinate-location shown in Figure 13 was used. Figure 13(a) shows the case when the ship is not in the centre of the missile-search-zone. Whereas Figure 13(b) shows the ship in the centre. The idea is to choose a point which lies within the missile-search-zone such that missile gets confused. Subroutine PØHAFF computes the position of the chaff (XC, YC) based on the logic shown in Figure 14. The computed XC, YC are passed as return parameters of the subroutine.

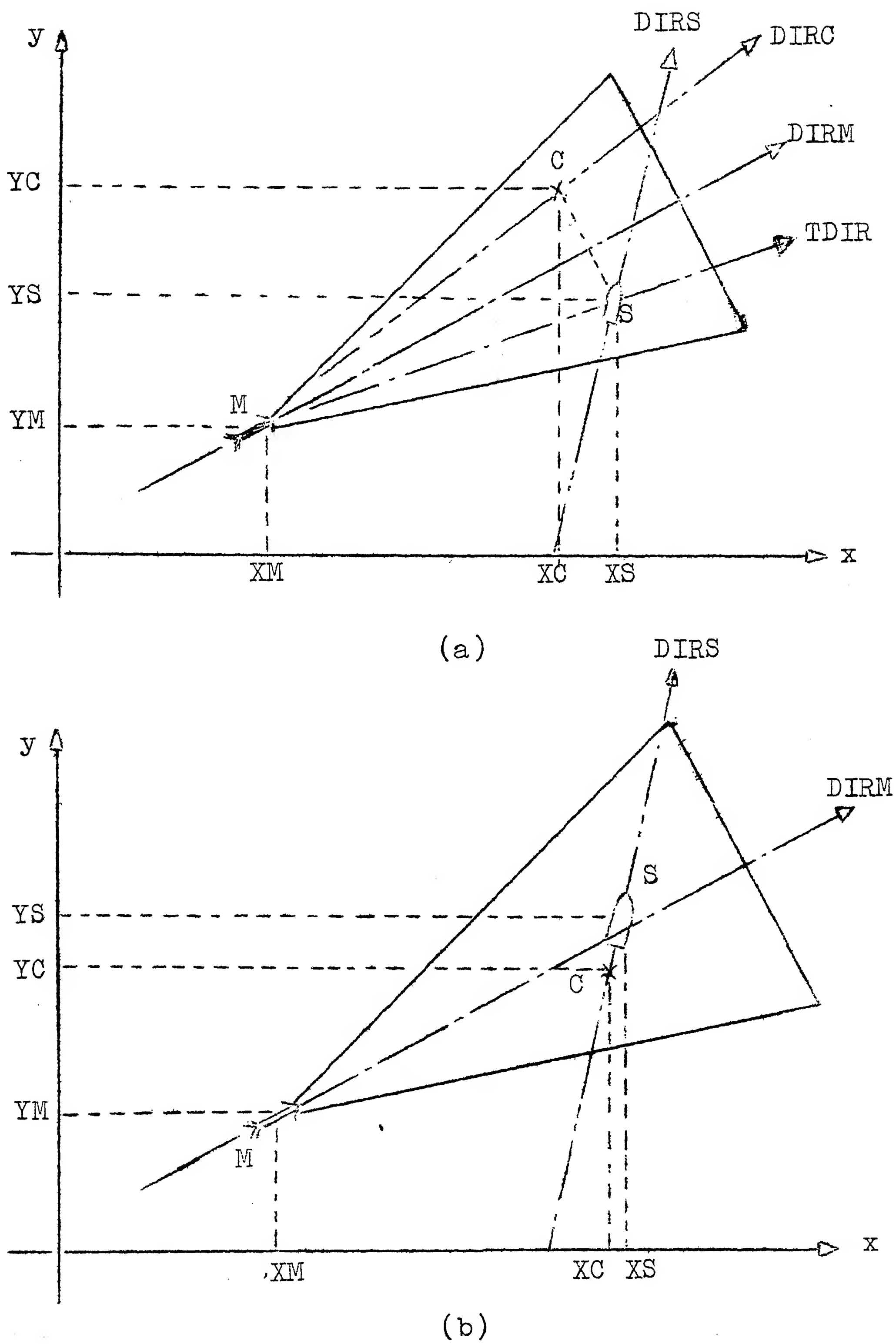



Fig. 13: Chaff Deployment Coordinates

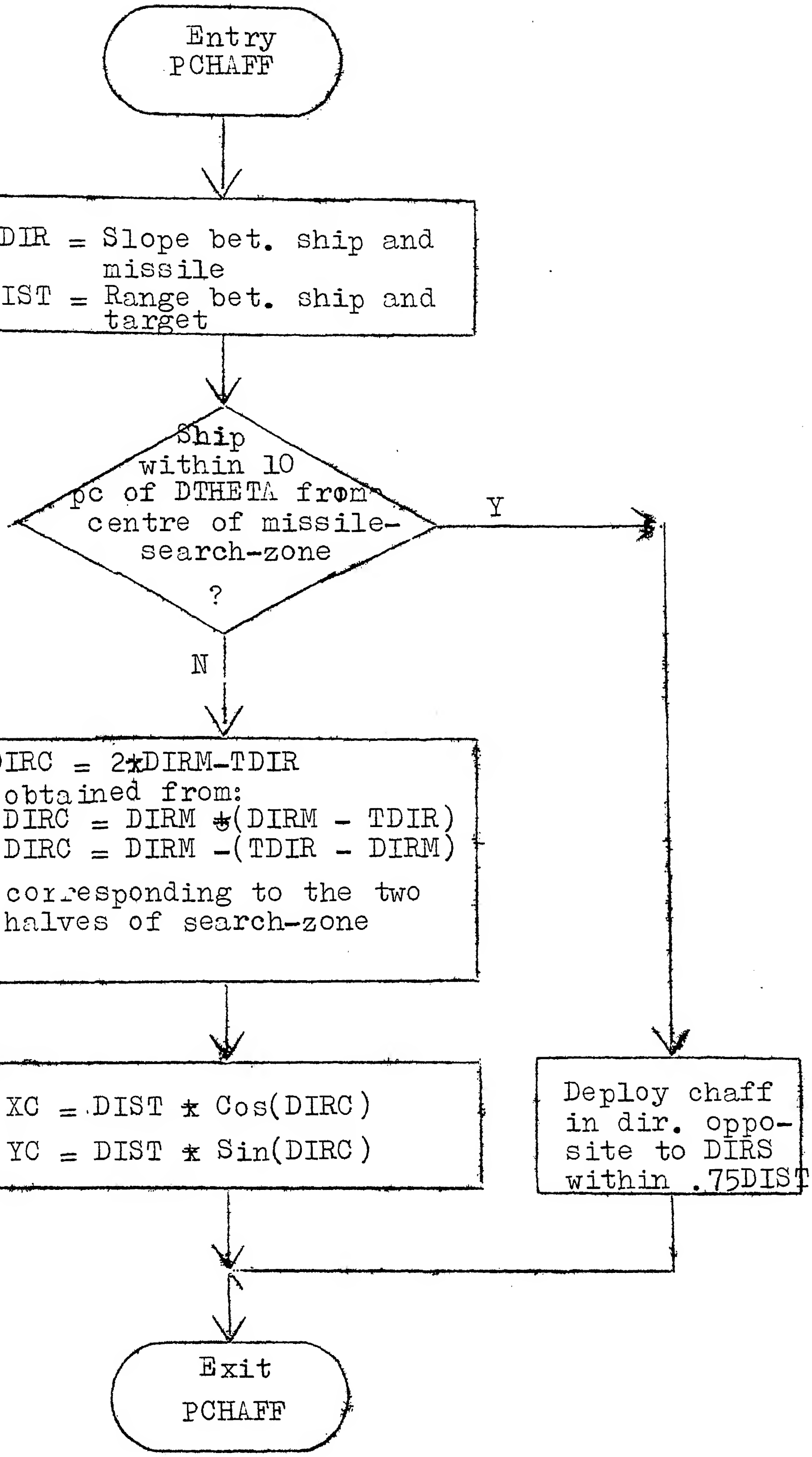



Fig. 14: Chaff Coordinate Computation

5-1.2 Firing, Blooming and Saturation: Once the chaff coordinates have been computed, chaff is fired and a flag CFIRE is set to 1. In practice, however, the reaction time of the ship's crew will delay the firing. This delay is, however, included in chaff's bloom time in ASMD game. After bloom-time (also called deployment time) elapses, chaff is supposed to bloom to its rated RCS. The rate of expansion after blooming is governed by the coefficient of expansion (COEFF) of chaff. The chaff, however, saturates after saturation time (STIME) and becomes ineffective as an electromagnetic energy reflector.

Subroutine CHRCS computes chaff RCS.

## 5-2. SCENARIO DEFINITION

Subroutine SCENRO enables the game players (namely the ship commander and the missile-commander) to choose their weapons and/or sensors from those available in the ASMD data base. In that sense, different combinations of platforms, weapons and sensors could be used for testing/evaluating a particular strategy. The subroutine is totally interactive in operation. Game-controller supplies/defines parameters such as wind speed and direction, probability of detection by sensors etc.

## 5-3. COMBAT TIME

ASMD game progresses every DELT (time-step). That is, events take place during a time step. TTIME represents combat time i.e., the time for which the game has been on.

## 5-4. GAME TACTICS

In the present work, the game tactics has been pre-programmed. But for bringing in more realism, the tactics could be supplied by the game player. The tactics for the ship [BEUL 78] which has been simulated is shown in Figure 15. Simulated tactics for missile is straight forward and hence no separate flowchart has been given. It involves:

(a) searching the target

(b) If target within search-zone lock on to it

(c) If more than one target within search-zone, lock-on to the target with largest RCS.

## 5-5. SURFACE WIND EFFECT

With passive EW tactics, wind plays an important role. A chaff cloud intended to be positioned at point A, may actually bloom at point B, if a strong wind is blowing from point A to B. And if point B is outside missile-search-zone, the entire purpose of deploying the chaff is lost. Subroutine WEFECT simulates the effect of the surface wind, as defined by the game controller at the time of game commencement. Given coordinates X,Y, WEFECT modifies X,Y depending upon the wind speed and direction.

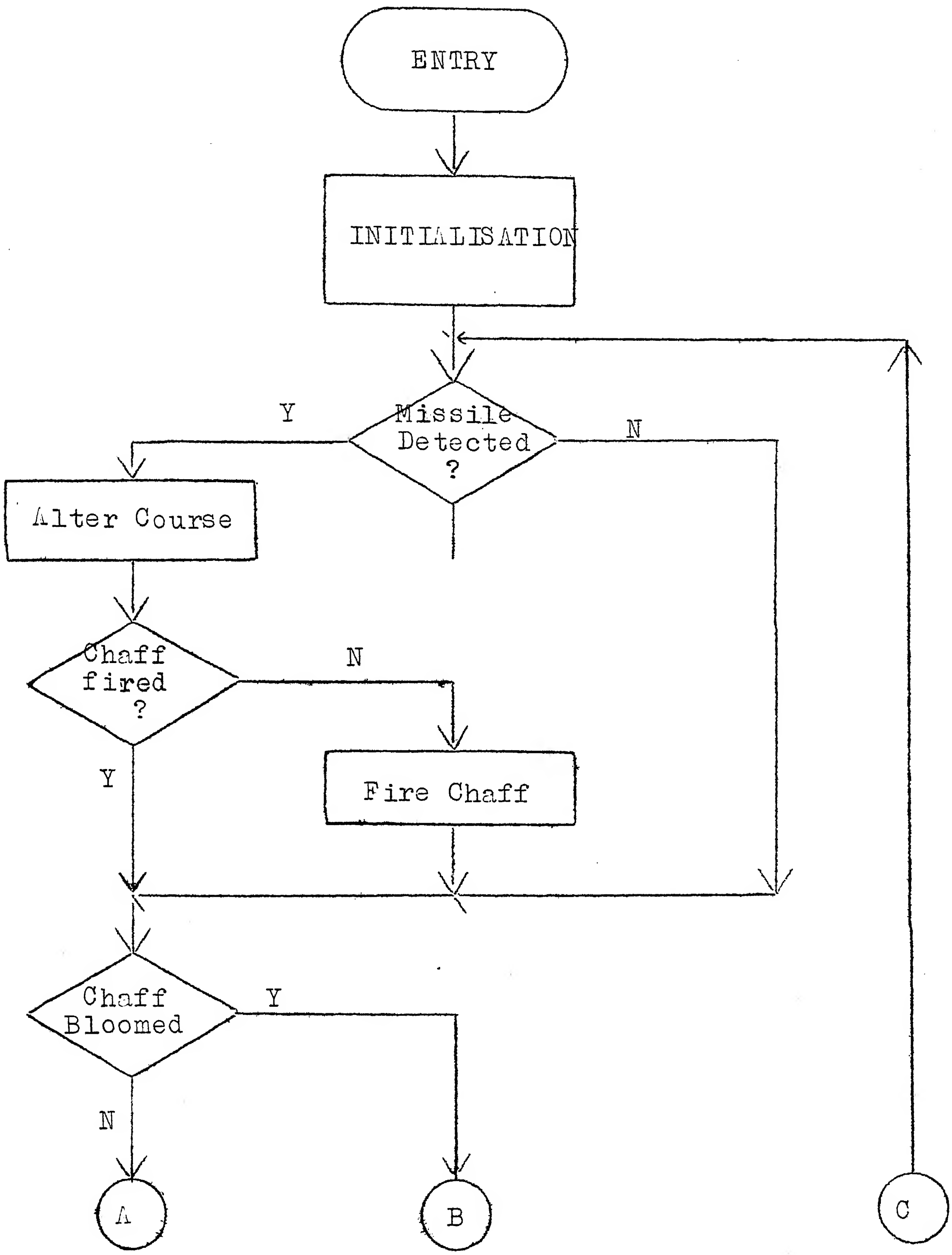



Fig. 15: ASMD Tactics (ship) (continued)

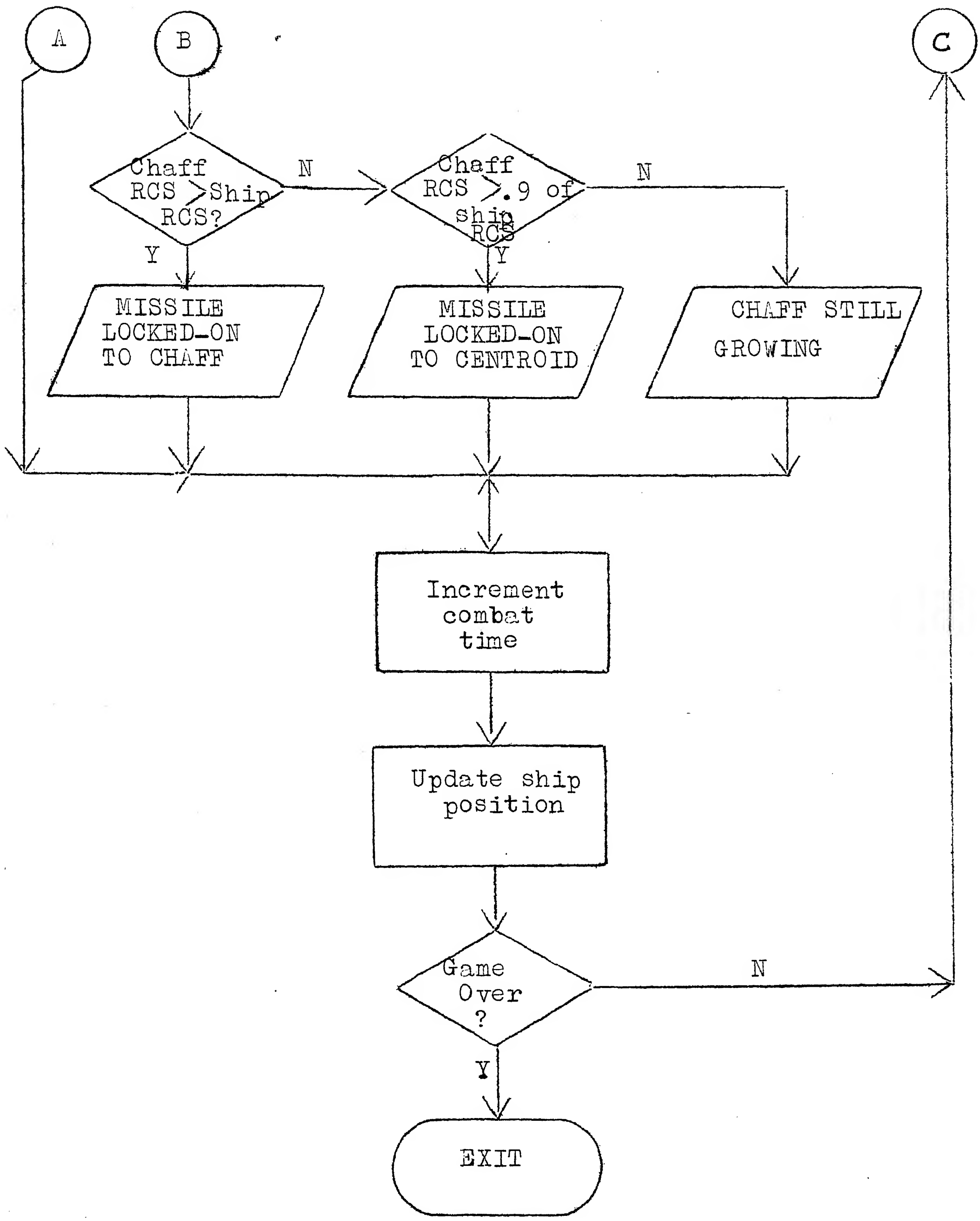



Fig. 15: ASMD Tactics (ship)

## 5-6. GAME TERMINATING CONDITIONS

The ASMD game terminates when any one of the following conditions is satisfied. The terminating checks are made by subroutine FINISH.

5-6.1 Termination Condition 1: Under this condition, the ASMD games ends if:

(a) Missile gets locked-on to the ship, AND

(b) Missile has approached the ship within kill-distance (KDIST).

In this case, missile is the winner and the ship gets destroyed/damaged.

5-6.2 Termination Condition 2: Under this condition, the ASMD game ends if:

(a) Missile has locked-on to the chaff, AND

(b) Missile has diverted to chaff AND,

(c) Ship is NOT in missile search zone.

In this case, ship is the winner and missile is successfully diverted to chaff.

5-6.3 Termination Condition 3: Under this condition, game ends if combat time exceeds the life time of the missile.

In this case, the missile gets self destroyed as its propulsion mechanism stops functioning and the sensors become inoperative after life-time elapses.

-

# 6. THE ASMD GAME

This chapter describes ASMD game implementation features and certain unquantifiables that can not be quantified in game simulations. The chapter should however, not be confused with a user's manual.

## 6-1. GAME CONFIGURATION

The ASMD game as reported in the present work was configured as shown in Figure 16. Ship and missile commanders' stations are connected to the game controller and through him to the computer system being used for war gaming. As shown, missile and ship commanders' stations are isolated from each other to provide realistic game environment.

The stations are nothing but terminals (TTY's) with facility for displaying and keying in alphameric information. The TTYs operate in time-sharing mode of the computer system.

## 6-2. GAME OUTCOME

ASMD game outcome is displayed on TTYs as well as printed out as a hard copy. The printout is essential for debriefing the game players. A sample game output is given at Appendix C.

## 6-3. GAME STATISTICS/ANALYSIS

For any game to be useful, means for its analysis must exist. Statistics local to every game played is included

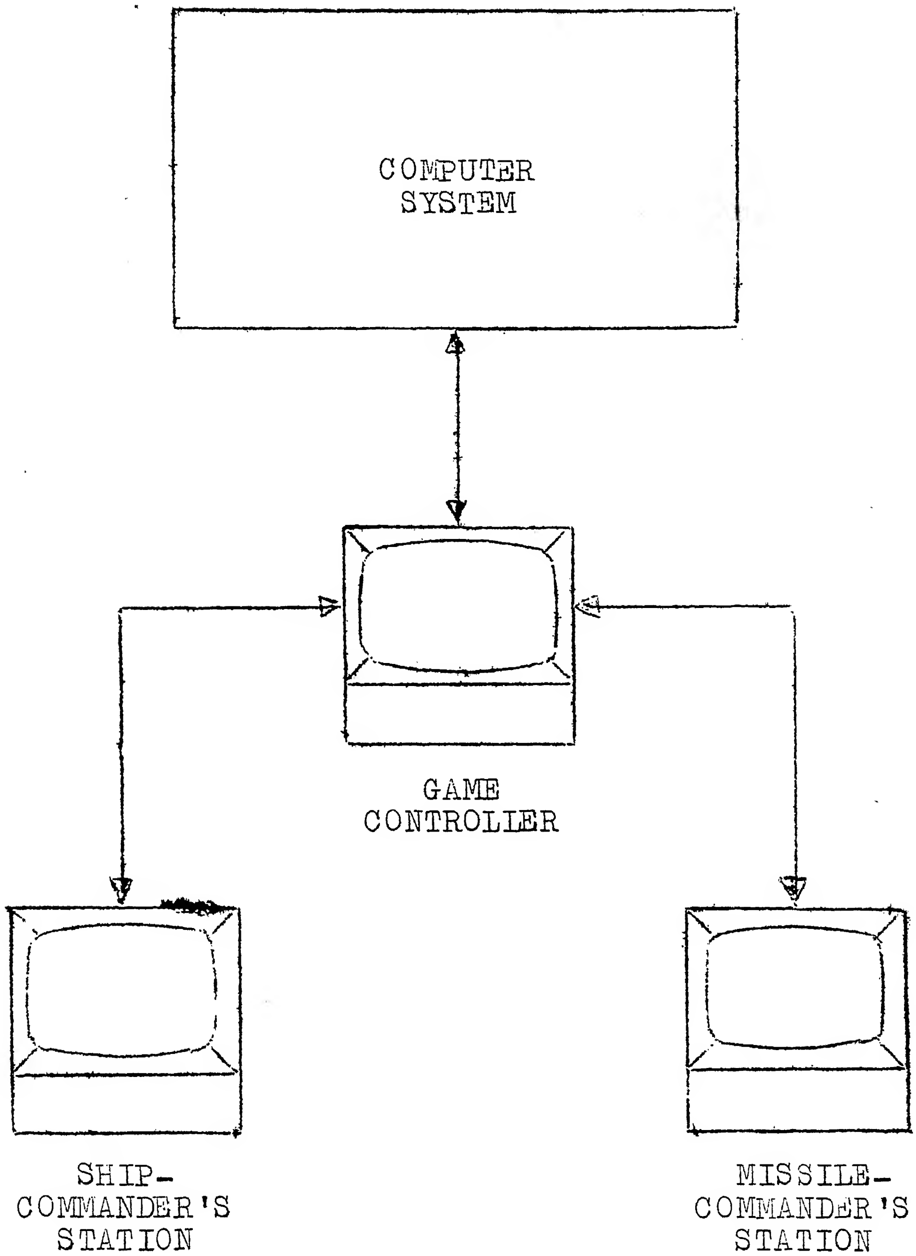



Fig. 16: ASMD Game Configuration

in the game-record which is printed. However, statistics on number of times game played with variation in parameters such as VS, Bloom time, type of ship etc. is given at Appendix D.

## 6-4. ON IMPLEMENTATION

It may be noted that out of the six months available for working on this project, no computer facility was available to the users for first $4\frac{1}{2}$ months. This break was caused due to the installation of a new machine at author's place of work. Following paragraphs describe some of the implementation dependent features in brief:

6-4.1 Computer System Available: DEC system 1090 installed at IIT-Kanpur was used as the gaming computer system. Some of the salient features of the system are:

- External memory cycle time : 1200nsec.
- Core memory : 256K words of 36 bits each
- Time-sharing facility with 20 TTY's connected up.

System configuration includes two 600 LPM line printers which were used for outputting the game-record.

6-4.2 Language Chosen: Despite the well-known shortcomings in FORTRAN [BHAR 79], it was chosen for implementing the ASMD game because it is the only language that has gained some familiarity in our Navy. ASMD game program was written in FORTRAN-10 (FORTRAN IV with extensions as implemented on DEC 10).

6-4.3 Software Development Time: The ASMD software was developed in stages. A subroutine-by-subroutine development and addition was carried out. The first subroutine was designed on 03 MAR 79 and the last was implemented on 23 JUL 79. That makes it close to five months which comes to an average of 7 lines a day!

## 6-5. THE UNQUANTIFIABLES

In any game simulation, there are always some parameters/quantifies that cannot be quantized. Examples are -

(a) Unit Effectiveness: We cannot say whether a particular unit taking part in a war game will be effective 100 percent or less? Because a unit's effectiveness depends upon factors like operational state of all weapons and sensors, logistic support available onboard, moral of ship's company (men on board) etc.

(b) Human Reaction/Behaviour: Reaction of a sailor at sea apart from personal considerations of health and psychology, also depend upon the sea state, moral of fellow sailors, overall war gains/losses etc.

Nevertheless simulation studies go on despite these unquantifiables and we learn to live with such errors in judgement.

# 7. SUGGESTIONS and CONCLUSION

During various stages of ASMD game development, we felt that much could have been done, was there more time available. Some of these are listed alongwith other suggestions for further work.

## 7-1. SUGGESTIONS FOR FURTHER WORK

Suggestions have been grouped into three categories namely, database, scenario and tactics. Apart from these three groups, an important and interesting area of work will be in linking a graphics display to the ASMD/NWGS game. It will help the game player in getting a visual picture of the game progress. Also, a radar detection model for the missile's attack radar could be considered.

7-1.1 Data Base: It will be worthwhile to carryout a quantitative study of the linked list structure suggested earlier for implementing the NWGS data base. Following action is suggested:

(a) Implement the linked list structure in a suitable language.

(b) Determine the optimum number of entries in the linked list structured data base for breaking even on overheads with the simple matrix structure.

(c) Study the control and use of data base for purposes other than NWGS gaming. May be, certain modifications will have to be made if we were to ask questions like: 'List all the surface skimmers with speed greater than .90 mach and range greater than 20nm?'

(d) Incorporate software locks and protection mechanism in the data base such that access to certain data is available to 'privilaged' users.

(e) Expand the data base to incorporate communications and jamming equipment.

7-1.2 Scenario: As compared to the minimum scenario reported in this report, suitable modifications/additions can be made to the ASMD game to make the models three-dimensional and then play the following:

(a) Capability of the ship to handle more than one target (say two missiles)

(b) An FPB with a sea-skimmer against a general purpose frigate.

(c) An FPB with a sea-skimmer against a general purpose frigate with air-support.

(d) Frigate against frigate.

(e) Number of FPB's against a convoy (say 3 frigates).

(f) Frigate and a submarine against a frigate and a submarine.

(g) Frigate, one submarine and one aircraft against a frigate, one submarine and one aircraft.

(h) Fleet against a fleet.

In addition, the game should provide for the simulation of intelligence reports, which decide the outcome of a war to a large extent.

7-1.3 Tactics: Effective use of jammers should be made in the tactics against a missile. Following is a suggested tactics:

(a) As soon as ship within missile-search-zone, fire two chaffs (C1,C2) with a small bloom time as shown in Figure 17(a).

(b) Switch on relevant band jammer on-board the ship.

(c) Missile may cease to transmit. Instead, it may home-on to jammer.

(d) Ship takes evasive action and keeps jammer on for 'some' time (time to be optimised with various runs).

(e) Ship ceases jamming. Fire another pair of chaffs (C3,C4) as shown in Figure 17(b).

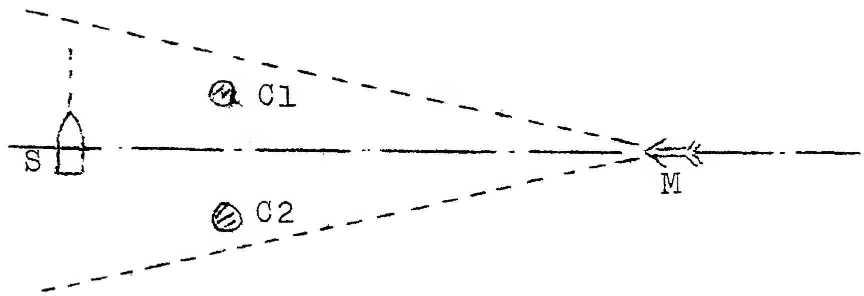
(f) Missile retransmits (since the ship jammer transmission has stopped) and looks for the ship.

(g) If C2 still within the search-zone (program should make sure it does, missile will lockon to C2.

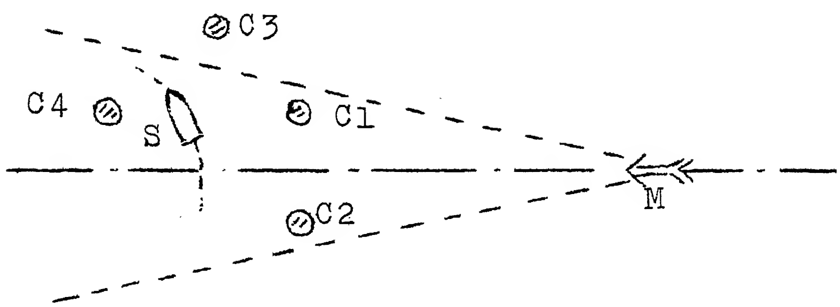
(h) Ship steers 'SAFE'.

Above is just one thought. Once jamming is introduced into the simulation, tactics can evolve with experimentation.

Furthermore, work can be done in a direction to write a program which accepts tactics from the game-player(s).




(a)




(b)

Fig. 17: A suggested ASMD-game Tactics

## 7-2. CONCLUSION

An ASMD game playing facility was developed and tested with a preprogrammed tactics and sample data. Data bases on platforms, radars, EW receivers, weapons and guided weapons were implemented and used in playing the ASMD game. The game play was interactive in nature with flexibility in scenario definition and choice of weapons/sensors. The ship and missile commanders were provided with two independent stations and the game was controlled by the game controller.

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# APPENDIX : A

( NWGS DATA BASE )

## A1: PLATFORM DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNITS |
|---|---|---|
| 1 | Ship Basic Classification | Code number |
| 2 | Length | Meters |
| 3 | Beam | Meters |
| 4 | Height (averaged with superstructures) | Meters |
| 5 | Draught | Meters |
| 6 | Maximum Speed | Knots |
| 7 | Cruising Speed | Knots |
| 8 | Endurance | Nautical Miles |
| 9 | Radius of Turn (At maximum speed ) | Meters |
| 10 | Carries Helecopter ? | Code number |
| 11 | Name or Ship I.D. | Code number |
| 12 | Maximum Wheel that can be applied | Degrees |
| 13 | Ship's RCS: BOWON | Meters**2 |
| 14 | Ship's RCS: BEAMON | Meters**2 |
| 15 | Future extension | - |

## APPENDIX : A

( NWGS DATA BASE )

### A2 : RADAR DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNIT |
|---|---|---|
| 1 | Radar Type | Code number |
| 2 | Frequency Band | Code number |
| 3 | Frequency : upper limit | MHz |
| 4 | Frequency : lower limit | MHz |
| 5 | Typical Ranges (Air/Su) | Nautical Miles |
| 6 | Antenna Rotation Rate | RPM |
| 7 | Peak Elec Power | KW |
| 8 | Receiver Sensitivity | dBm |
| 9 | Antenna Gain | dB |
| 10 | Acquire variable | Logical |
| 11 | ECCM Features (I) | Code number |
| 12 | ECCM Features (II) | Code number |
| 13 | Receiver Gain | dB |
| 14-15 | Future expansion | - |

APPENDIX : A

( NWGS DATA BASE )

## A3 : ESM RECEIVER DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNIT |
|---|---|---|
| 1 | Type of Receiver | Code number |
| 2 | Frequency | Code number |
| 3 | Upper Frequency Limit | MHz |
| 4 | Lower Frequency Limit | MHz |
| 5 | Receiver Sensitivity | dBm |
| 6 | Receiver Antenna Gain | dB |
| 7-10 | Future expansion | - |

# APPENDIX : A

( NWGS DATA BASE )

## A4 : SONAR DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNITS |
|---|---|---|
| 1 | Sonar Type | Code number |
| 2 | Beam Switching Rate (if applicable) | Integer |
| 3 | Lower Frequency Limit | KHz |
| 4 | Upper Frequency Limit | KHz |
| 5 | Maximum Range | Kms |
| 6 | Scan Characteristics | Code number |
| 7 | Peak Elec Power | KW |
| 8 | Receiver Sensitivity | dBm |
| 9 | Depth Capability | Meters |
| 10 | Rear Blanking Angle | Degrees |
| 11 | Aquire Variable | Logical |
| 12 | Transducer Gain | dB |
| 13-15 | Future expansion | - |

APPENDIX : A

( NWGS DATA BASE )

## A5 : WEAPONS DATA BASE CHARACTERISTICS

| SL | PARAMETERS | UNITS |
|---|---|---|
| 1 | Type of Weapon | Code number |
| 2 | Weapon Class | Code number |
| 3 | Minimum Intercept Range | Kms |
| 4 | Maximum Intercept Range | Kms |
| 5 | Type of Warhead | Code number |
| 6 | Burst Radius or Rated RCS after Bloom Time (CHAFF) | Meters or Meters**2 |
| 7 | Rate of Fire | RPM |
| 8 | Hit/Kill Probability (if 1, indicates CHAFF data) | % |
| 9 | Barrel/Tube Diameter or Deoployment Time (CHAFF) | mm or Seconds |
| 10 | Row Value in Guided Weapons Data base (if applicable) or Saturation Time (CHAFF) | Integer or Seconds |
| 11 | Row value in Radar data base (if applicable) for data on Guided Missile's radar | Integer |
| 12-15 | Future expansion | - |

# APPENDIX : A

( NWGS DATA BASE )

## A6 : GUIDED WEAPONS DATA BASE CHARACTERISTICS

| SL | PARAMETER | UNITS |
| --- | --- | --- |
| 1 | Row Value in Weapons Data Base | Integer |
| 2 | Missile RCS | Meters**2 |
| 3 | Missile Speed | (MACH no. *100) |
| 4 | Guidance (Cruise Mode) | Code number |
| 5 | Frequency(Cruise Mode) | MHz |
| 6 | Lower Range from Launcher (Cruise Mode) | Km |
| 7 | Upper Range from Launcher (Cruise Mode) | Km |
| 8 | Altitude of Flight (Cruise Mode) | Meters |
| 9 | Maximum Maneuvouring Allowed (Cruise Mode) | Degrees |
| 10 | Guidance (Attack Mode) | Code number |
| 11 | Frequency (Attack Mode) | MHz or Band |
| 12 | Maximum Range from Target when Search Begins (Attack Mode) | Km |
| 13 | Maximum Maeuvouring Allowed (Attack Mode) | Degrees |
| 14 | Altitude of Flight (Attack Mode) | Meters |
| 15 | Maximum Load Factor | *g |
| 16 | ECCM Features | Code number |
| 17-20 | Future expansion | - |

```
C>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

C                 APPENDIX : B
C                 ------------

C        ( ASMD PROGRAM LISTING )

C   ASMD (ANTI-SHIP MISSILE DEFENCE)
C   PROG TO STIMULATE AND PLAY THE ASMD GAME
C   CREATION TIME : MAR-JUL 1979.
C   AUTHOR : [6100,60006]
C   DESCR OF VARS:
C          BEAMON   SHIP'S RCS WHEN MISSILE BEAM-ON
C          BOWON    SHIP'S RCS WHEN MISSILE BOW-ON
C          CLOCK    FLAG TO INDICATE IF MISSILE
C                   LOCKED-ON TO THE CHAFF
C          CSPEED   SHIP'S CRUISE SPEED
C          DEGRAD   RADIANS TO DEGREE CONVERSION FACTOR
C          DELT     TIME INCREMENT STEP
C          DTHETA   SWEEP ANGLE OF MISSILE SEEKER HEAD
C          JEVASE   FLAG =1,WHEN EVASIVE ACTION COMPLETED
C          JSILEN   FLAG =1,WHEN 'RADAR SILENCE'
C                   IS OPERATIVE
C          JUNIT    LOGICAL UNIT NO OF  SHIP'S
C                   COMMANDER'S STATION (TTY)
C          KDIST    KILL DISTANCE FOR MISSILE TO
C                   DESTROY THE SHIP
C          KOUNT1   TIME COUNTER.STARTS AFTER MISSILE
C                   LOCKED-ON TO CHAFF
C          MAXRAD    RADIUS OF TURN OF THE SHIP AT
C                   MAXIMUM SPEED
C          MUNIT    LOGICAL UNIT NO OF MISSILE
C                   COMMANDER'S STATION (TTY)
C          RSEEK    MAX RANGE OF MISSILE SEEKER HEAD
C          TLIFE    LIFE TIME OF THE MISSILE
C          TLOCK    FLAG TO INDICATE IF SHIP WITHIN
C                   SEEKER-SEARCH-ZONE
C          TLOCK2   FLAG TO INDICATE IF CHAFF WITHIN
```

```
C                 SEEKER-SEARCH-ZONE
C          WHEEL  EFFECTIVE ANGLE OF TURN AT
C                 OPERATING SPEED 'VS'
C   VS,VM ARE INPUT IN knots
C   PROG STORED IN FILE 98.FOR
C   ALL SUBROUTINES LISTED IN ALPHABETICAL
C          AFTER THE MAIN PROGRAM


        DIMENSION IDATE(2),JRND(5)
        INTEGER SHIP(15),RADAR(5,15),WEAPON(5,15),
        1GWEPON(2,20),ESM(2,10)
        REAL KDIST,MAXRAD
        INTEGER TLOCK,CFIRE,CLOCK

        COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
        COMMON /LAB1/DEGRAD
        COMMON /LAB2/RSEEK
        COMMON /LAB3/IU
C       COMMON /LAB4/ ---Used elsewhere
        COMMON /LAB5/TTIME
        COMMON /LAB6/VOLUME,COEFF,DTIME,STIME
        COMMON /LAB7/XC,YC
        COMMON /LAB8/JSHIP,JCHAFF
        COMMON /LAB9/WSPEED,DIRW
        COMMON /LAB10/DELT
        COMMON /LAB11/TLIFE,KDIST
        COMMON /LAB12/TLOCK,CFIRE,CLOCK
        COMMON /LAB13/BOWON,BEAMON
        COMMON /LAB14/SHIP,RADAR,WEAPON,GWEPON,ESM
        COMMON /LAB15/MUNIT
        COMMON /LAB16/JBELL
        COMMON /LAB17/DTHETA
        COMMON /LAB18/JUNIT
        COMMON /LAB19/DIST
        COMMON /LAB20/PI,PI4CUB,VLITE,THRESH
        COMMON /LAB21/MR,IGW,MW

        DATA JSHIP,JCHAFF/5HSHIP ,5HCHAFF/
        DATA JFAST,JSLOW/1HF,1HS/

        DEGRAD=180.*7./22.
        PI=22./7.
        PI4CUB=64.*PI*PI*PI
        VLITE=3E8
```

```
      MUNIT=31
      JUNIT=32
      JBFLL=14
      JU=34
      IU=33
      JB1=1
      JB2=2
      JB4=4
      JB8=8
      TYPE 16
16    FORMAT(' TYPE BELOW MISSILE-COMMANDER''S DEVICE-ID')
      ACCEPT 17,JNAME
17    FORMAT(A5)
      TYPE 20
20    FORMAT(' TYPE BELOW SHIP-COMMANDER''S DEVICE-ID')
      ACCEPT 17,JNAME2
      OPEN(UNIT=JUNIT,DEVICE=JNAME2)
      OPEN(UNIT=MUNIT,DEVICE=JNAME)
      CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,830)
      CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,770)
770   FORMAT(' YOU ARE HEREBY DESIGNATED'/
     1' THE SHIP-COMMANDER.')
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,830)
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,840)
840   FORMAT(' YOU ARE HEREBY DESIGNATED'/
     1' THE MISSILE-COMMANDER.')

      CALL SCENRO

      RSEEK=GWEPON(IGW,12)*1000
      OPEN(UNIT=IU,FILE='98.OUT')
D     DO 200 KK=1,10
      OPEN(UNIT=JU,FILE='98IP.DAT')
      TYPE12
12    FORMAT(' TYPE IN CHAFF''S DTIME AND '/
     1' COEFF IN FREE FORMAT')
      ACCEPT *,DTIME,COEFF
      TYPE 15
15    FORMAT(' TYPE IN WIND-SPEED(KNOTS) AND '/
     1' WIND-DIRECTION IN FREE FORMAT')
      ACCEPT *,WSPEED,DIRW
```

```
      WRITE(TU,972) WSPEED,DIRW
972   FORMAT(80X,'WIND-SPEED=',F6.1,' KNOTS.'/
     180X,'WIND-DIRECTION=',F6.1,' DEGREES')
      TYPE 13
13    FORMAT(' TYPE IN THE NO OF TIMES YOU '/
     1' WISH TO PLAY THE GAME')
      ACCEPT *,NN
      DO 100 K=1,NN
      CALL BELL(MUNIT,JB4)
830   FORMAT(' THIS IS ASMD GAME MONITOR.'/
     1' LET''S PLAY THE ASMD GAME.'/
     2' DO AS I TELL YOU. GOOD LUCK.')
51    CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,800)
800   FORMAT(' TYPE BELOW MISSILE INITIAL POSITION')
      READ(MUNIT,*) XM,YM
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,820)
820   FORMAT(' TYPE BELOW MISSILE COURSE')
      READ(MUNIT,*) DIRM
      WRITE(TU,960) K
960   FORMAT(10X,' RUN',I3)
      CALL BELL(JUNIT,JB2)

      WRITE(JUNIT,10)SHIP(7),SHIP(6)
10    FORMAT(' SUPPLY INIT POSITION,HEADING &'/
     1' SPEED OF SHIP IN FREE FORMAT'/
     2' PLEASE NOTE THAT YOUR SHIP''S'/
     3' CRUISING SPEED=',I3,' KNOTS, AND'/
     4' MAXIMUM SPEED=',I3,' KNOTS')
      READ(JUNIT,*)XS,YS,DIRS,VS
      XS=XS*1000.
      YS=YS*1000.
      XM=XM*1000.
      YM=YM*1000.
      CALL RANGE(XS,YS,XM,YM,DISTIN)
      IF(DISTIN.LE.RSEEK) GO TO 50
      CALL BELL(JUNIT,JB2) ; CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,821) DISTIN,RSEEK
821   FORMAT(' SINCE INITIAL RANGE=',F8.2,
     1' METERS'/' IS MORE THAN MISSILE-SEEKER-
     2HEAD RANGE(=',F8.2,' ) METERS,'/
     3' IT WILL NOT BE A USEFUL GAME-PLAY.'/
     4' PLEASE RE-INITIALISE.')
      WRITE(JUNIT,821) DISTIN,RSEEK
```

```
      DIST=DISTIN
      GO TO 51

50    WRITE(TU,900   )XS,YS,DIRS
900   FORMAT(10X,' SHIP''S  INITIAL POSITION :  X=',F8.2,
     1'  Y=',F8.2,' KMS'/20X,'  COURSE=',F8.2,' DEGREES')
      WRITE(TU,910   ) XM,YM,DIRM
910   FORMAT(10X,' MISSILE''S  INITIAL POSITION :  X=',F8.2,
     1'  Y=',F8.2,' KMS'/
     120X,'  COURSE=',F8.2,' DEGREES'/)
      WRITE(IU,920   )
920   FORMAT(10X,'TIME ',6X,'XS',8X,'YS',8X,'XM',8X,
     1'YM',5X,'DIRS',5X,'DIRM  RANGE')

C  SELECT APPROPRIATE AE ROTATION RATE
      CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,19)
19    FORMAT(' TYPE SCANNING MODE OF RADARS.'/
     1' FOR FAST TYPE ''F''.'/
     2' FOR SLOW TYPE ''S''.')
      READ(JUNIT,18)JSCAN
18    FORMAT(A1)
      TYPE 24,JBELL
24    FORMAT(A5)
      TYPE 21
21    FORMAT(' TYPE THE PROBABILITY OF DETECTION FOR '
     1'SENSORS.'/' (CONSIDER SEA-CLUTTER ETC ALSO)'/
     2' USE A VALUE BETWEEN 0 AND 1.')
      ACCEPT *,THRESH
      NR=MR-1
      CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,750)
750   FORMAT(' DO YOU WISH TO ENFORCE RADAR SILENCE ?'/
     1' IF YES,TYPE A ''1'',ELSE ''0''')
      READ(JUNIT,760) JSILEN
760   FORMAT(I2)
      TYPE 24,JBELL
      TYPE 22,JSILEN
22    FORMAT(' JSILEN(RADAR SILENCE) AS SUPPLIED BY'/
     1' SHIP-COMMANDER=',I2)
      DO 300 I300=1,NR
      NRTEMP=RADAR(I300,6)/100
      NROT=RADAR(I300,6)
      IF(NRTEMP.GT.0) NROT=NRTEMP
      IF(JSCAN==JFAST)
```

```
        1 NROT=RADAR(I300,6)-NRTEMP*100
          JRND(I300)=60/NROT
          TYPE 23,I300,JRND(I300)
23        FORMAT(' ON-BOARD RADAR-',I2,' TAKES'/
          1I3,' SECONDS TO COMPLETE ONE REV.')
300       CONTINUE

          CALL DATE(IDATE)
          WRITE(TU,990) IDATE
990       FORMAT(80X,'GAME PLAYED ON ',2A5)
          CALL TIME(IH,IS)
          WRITE(IU,80    ) ,IH,IS
80        FORMAT(80X,'GAME STARTED AT ',2A5)

C   *****------READ FROM WEAPON/PLATFORM DATA-----*******
          DELT=1.
          VM=GWEPON(IGW,3)
          VM=VM*1120./3.6E5
          VM=VM*1000.
          BOWON=SHIP(13)
          BEAMON=SHIP(14)
          DTHETA=GWEPON(IGW,13)
          RSEEK=GWEPON(IGW,12)*1000.
          MAXRAD=SHIP(9)
          CSPEED=FLOAT(SHIP(7))*1830./3600.
          VSMAX=SHIP(6)
          TTIME=0.
          TLIFF=60.
          H=SHIP(4)
          SL=SHIP(2)
D         DTIME=5.
          STIME=WEAPON(MW-1,10)
D         COEFF=50.
          VOLUME=WEAPON(MW-1,6)
          VS=1830.*VS/3600.
          KDIST=VM*DELT
          VSMAX=1830.*VSMAX/3600.
          WSPEED=WSPEED*1830./3600.
          RADIUS=MAXRAD-.1*(VSMAX -VS)
          WHEELR=VS*DELT/RADIUS
          WHEEL=DEGRAD*WHEELR
C   *****------*************************************
          WRITE(IU,971) DTIME,COEFF,VOLUME
971       FORMAT(80X,'DATA DTIME,COEFF,VOLUME/',3F6.0,'/')
```

```
C   INITIALISE ALL FLAGS
          MAUTO=0
          TLOCK=0
          TLOCK2=0
          CFIRE=0
          JDONE1=0
          JDONE2=0
          JDONE3=0
          JDONE4=0
          CLOCK=0
          KOUNT1=0
          JDTECT=0
C   INITIALISATION OVER. GAME COMMENCES

C   DETECTION BY SENSORS:
 30       JTIME=TTIME
          IF(JSILEN==1) GO TO 40

C   DETECTION BY ON-BOARD RADARS
          IF(CFIRE==1) GO TO 44
          DO 310 I310=1,NR
          JDIV=JTIME/JRND(I310)
          JREM=JTIME-JDIV*JRND(I310)
          IF(JREM.NE.0) GO TO 310
          IF(RADAR(I310,10)==1) GO TO 41
          ISENS=I310
          CALL RDTECT(ISENS,JSILEN,JAQUIR)
          IF(JAQUIR==1) JDTECT=1
 310      CONTINUE
          GO TO 42

 40       CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,720)
 720      FORMAT(' RADAR SILENCE IS ON.'/
          1' HENCE NO RADAR DETECTION.')
          GO TO 42

 41       CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,730) ISENS
 730      FORMAT(80X,' TARGET ALREADY DETECTED BY RADAR'
          1'-',I2,'.')

 44       CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,731)
 731      FORMAT(80X,'SINCE CHAFF HAS BEEN FIRED.'/
```

```
      181X,'RADAR OPERATION CEASES.')

C  PASSIVE DETECTION BY ESM-RECEIVERS
42      CALL BELL(JUNIT,JB2)
        CALL SKIP10(JPRINT)
        IF(JPRINT==0) GO TO 43
        WRITE(JUNIT,740)
740     FORMAT(80X,'PASSIV DETECTION :'/)
        WRITE(IU,740)
43      IESM=1
        IPASS=1
        CALL RDTECT(IESM,IPASS,JDET)
        IF(JDET==1) JDTECT=1

C  DECISION MAKING
        IF(CFIRE.EQ.1) GO TO 35
        XT=XS ; YT=YS
35      IF(TLOCK==0) CALL MISRCH(DTHETA,XS,YS,JSHIP,TLOCK)
        IF(CLOCK==1.AND.TLOCK2==0) CALL MISRCH(DTHETA,
        1XC,YC,JCHAFF,TLOCK2     )
        IF(TLOCK==0.AND.MAUTO==0) CALL GIDNCE(DTHETA,MAUTO)
        IF(TLOCK==1.OR.MAUTO==1) CALL MISMOD(XT,YT,DTHETA)
        IF(TLOCK==1.OR.JDTECT==1) CALL COURSE(WHEEL,JEVASE)
        IF(JEVASE==1.AND.JDONE3==0) GO TO 37
        GO TO 38
37      CALL BELL(JUNIT,JB2)
        WRITE(JUNIT,710) SHIP(6)
710     FORMAT(80X,'EVASIVE ACTION COMMENCED.'/
        180X,'SHIP''S SPEED INCREASED TO',I3,' KNOTS.')
        RADIUS=MAXRAD-.1*(VSMAX-VS)
        WHEELR=VS*DELT/RADIUS
        WHEEL=WHEELR*DEGRAD
        JDONE3=1

C  CHAFF RCS TESTING
38      IF(TLOCK==1.AND.JDONE1==0.AND.JDTECT==1)
        1CALL PCHAFF(TLOCK,DTHETA,JDONE1)
        IF(JDONE1==0) GO TO 34
        IF(JDONE2==1) GO TO 31
        CFIRE=1
        TCHAFF=TTIME
        WRITE(IU,991) TCHAFF
991     FORMAT(80X,'CHAFF FIRED AT',F5.0,' SECONDS')
        CALL RANGE(XS,YS,XC,YC,DISTSC)
        WRITE(IU,992) DISTSC
```

```
C   TESTING FOR GAME TERMINATION COMMENCES
33        CALL FINISH(JCONT)
          IF(JCONT==1) GO TO 30
100       CONTINUE
          CLOSE(UNIT=JU)
200       CONTINUE
          CALL BELL(MUNIT,JB8)
          WRITE(MUNIT,890)
890       FORMAT(' THANK YOU FOR CO-OPERATION.'/
          1' I ENJOYED PLAYING THE GAME WITH YOU.')
          CALL BELL(JUNIT,JB8)
          WRITE(JUNIT,890)
          STOP    'PROPER STOP'
          CLOSE(UNIT=IU)
D         CLOSE(UNIT=JU)
          CLOSE(UNIT=MUNIT)
          CLOSE(UNIT=JUNIT)
          END
```

```
C   S/R ANGMOD : COMPUTES Mod-360 OF 'ANGLE'

          SUBROUTINE ANGMOD(ANGLE)
          SIGN=1.
          IF(ANGLE.LT.0.)GO TO 10
          IF(ANGLE.LT.360.)RETURN
          SIGN=-1.
10        ANGLE=ANGLE+360.*SIGN
          RETURN
          END
```

```
C   S/R BELL : TO SEND 'JNUM' NO OF 'BELL's TO
C                 LOGICAL DEVICE 'MUNIT'

          SUBROUTINE BELL(MUNIT,JNUM)
          DATA JBELL/14/
          DO 20 I=1,JNUM
```

```
      WRITE(MUNIT,10) JBELL
10    FORMAT(A5)
20    CONTINUE
      RETURN
      END


C   S/R CHRCS : TO COMPUTE RCS OF CHAFF
C     VOLUME  RATED VOLUME OF EXPLOSION OF CHAFF
C     COEFF   COEFFICIENT OF EXPANSION OF CHAFF CLOUD
C     DTIME   CHAFF DEPLOYMENT/BLOOM TIME IN SECONDS
C     STIME   CHAFF SATURATION TIME IN SECONDS

      SUBROUTINE CHRCS(CFIRE,TCHAFF,CRCS)
      COMMON /LAB6/VOLUME,COEFF,DTIME,STIME
      COMMON /LAB5/TTIME
      INTEGER CFIRE
      COMMON /LAB3/IU

      IF(CFIRE.EQ.0) GO TO 30
      TT=TTIME-TCHAFF
      IF(TT.LE.DTIME) GO TO 10
      IF(TT.GE.STIME) GO TO 20
      CRCS=VOLUME+COEFF*( TT-DTIME)
      RETURN

10    CRCS=0
      WRITE(IU,90)
90    FORMAT(80X,'CHAFF YET TO BLOOM')
      RETURN

20    CRCS=0
C      ZERO HERE MEANS INEFFECTIVE RCS
      WRITE(IU,91)
91    FORMAT(80X,'CHAFF HAS SATURATED AND THUS '
     1'BECOME INEFFECTIVE')
      RETURN

30    WRITE(IU,93)
93    FORMAT(10X,'CHAFF NOT YET FIRED!'/
     110X,'HOW DID YOU ENTER THIS ROUTINE ?')
      RETURN
      END
```

```
C    S/R COURSE: COMPUTES SHIP'S NEXT COURSE DURING
C                AN EVASIVE ACTION

          SUBROUTINE COURSE(WHEEL,JEVASE)

          COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
          COMMON /LAB1/DEGRAD
          COMMON /LAB3/IU

          JEVASE=0
          CALL ANGMOD(DIRS)
          CALL SLOPEC(XM,YM,XS,YS,SLOPE)
          DIFF=ABS(SLOPE-DIRS)
          IF(DIFF.LE..1) GO TO 10
          IF(DIFF.LE.WHEEL) GO TO 20
          SIGN=1.
          CSIGN=1.
          IF(DIFF.GE.180.) SIGN=-1.
          IF(SLOPE.LT.DIRS) CSIGN=-1.
          DIRS=DIRS+WHEEL*SIGN*CSIGN
          RETURN

 10       CALL SKIP10(JPRINT)
          IF(JPRINT.EQ.0) RETURN
          WRITE(IU,950)
 950      FORMAT(80X,'EVASIVE ACTION COMPLETED')
          JEVASE=1
          RETURN

 20       DIRS=SLOPE
          RETURN
          END


C    S/R FINISH : TEST FOR GAME TERMINATION

          SUBROUTINE FINISH(GAMEON)
          INTEGER GAMEON
```

```
C   ENTER HERE WHEN CONDITION-1 TRUE
50        WRITE(TU,70    ) ,XM,YM,XS,YS,TTIME
70        FORMAT(10X,' MISSILE AT',2F10.2,' DESTROYES THE '/
         110X,'SHIP AT',2F10.2/
         210X,' AT TIME=',F5.0,'SECONDS')
          CALL BELL(MUNIT,JB4)
          WRITE(MUNIT,70) XM,YM,XS,YS,TTIME
          CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,70) XM,YM,XS,YS,TTIME
          WRITE(TU,71) DIST,KDIST
71        FORMAT(10X,'AT RANGE =',F10.2,', WHEREAS ',
         1'KILL DISTANCE=',F10.2)
          CALL BELL(MUNIT,JB4)
          WRITE(MUNIT,71) DIST,KDIST
          GO TO 45

81        WRITE(TU,981)XM,YM,XC,YC,TTIME
981       FORMAT(10X,' MISSILE AT',2F10.2,' GETS LOST '/
         110X,'IN THE CHAFF AT',2F10.2/
         210X,' AT TIME=',F5.0,' SECONDS.'/
         310X,' SHIP THUS EMERGES VICTOR')
          CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,981) XM,YM,XC,YC,TTIME
          CALL BELL(MUNIT,JB4)
          WRITE(MUNIT,981) XM,YM,XC,YC,TTIME
          GO TO 45

C   ENTER HERE WHEN CONDITION-2 TRUE
83        WRITE(TU,983) XM,YM,XC,YC,TTIME
983       FORMAT(10X,' MISSILE AT',2F10.2,' METERS,'/
         110X,'DIVERTED TO CHAFF AT',2F10.2,' METERS,'/
         210X,' AT TIME=',F5.0,' SECONDS.'/
         310X,' SHIP THUS EMERGES VICTOR.')
          WRITE(TU,984) SLOPMS,SLOPMC
984       FORMAT(10X,'MISSILE-SHIP BEARING=',
         1F5.1,' DEGREES'/10X,'MISSILE-CHAF BEARING='
         2,F5.1,' DEGREES'/10X,'THEREFORE SHIP
         3 OUTSIDE MISSIL-SWEEP-ANGLE.')
          CALL BELL(MUNIT,JB4)
          WRITE(MUNIT,983) XM,YM,XC,YC,TTIME
          WRITE(JUNIT,983) XM,YM,XC,YC,TTIME
          CALL BELL(JUNIT,JB2)

45        WRITE(TU,982) DISTMC,DIST,KDIST
982       FORMAT(10X,'GAME RECORD AT TERMINATION :',
```

```
      1' MISSILE-CHAFF RANGE=',F8.2,/
      239X,'SHIP-MISSILE RANGE=',F8.2/
      339X,'MISSILE KILL RANGE=',F8.2)
      CALL TIME(IH,IS)
      WRITE(IU,90   ) ,IH,IS
      RETURN
      END
```

```
C   S/R GIDNCE : TO SIMULATE CRUISE-PHASE GUIDANCE
C                FOR THE MISSILE
C         MAUTO  FLAG TO INDICATE IF INERTIAL
C                GUIDANCE IS ON
C                =0,FOR COMMAND GUIDANCE

      SUBROUTINE GIDNCE(DTHETA,MAUTO)

      COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
      COMMON /LAB3/IU
      COMMON /LAB1/DEGRAD
      COMMON /LAB4/TDIR
      COMMON /LAB15/MUNIT
      REAL NEWDIR

      DATA JSECON,JINIT/1HC,1HI/
      DATA JB1,JB2,JB4,JB8/1,2,4,8/

      TYPE 10,DIRM,TDIR
10    FORMAT(10X,'MISSILE UNABLE TO LOCK-ON.'/
      110X,'BECAUSE MISSILE COURSE=',F7.2/
      210X,'WHEREAS HOME-ON COURSE=',F7.2/
      310X,'TYPE ''C'' FOR COMMAND-GUIDANCE,AND'/
      410X,'''I'' FOR INERTIAL-GUIDANCE.')
      WRITE(IU,10)DIRM,TDIR,DTHETA
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,10) DIRM,TDIR

      READ(MUNIT,20)JREPLY
20    FORMAT(A1)
      IF(JREPLY.EQ.JSECON) GO TO 110
      IF(JREPLY.NE.JINIT) GO TO 120
      CALL BELL(MUNIT,JB4)
```

```
          WRITE(MUNIT,40) DTHETA
40        FORMAT(' TYPE IN THE NEW COURSE'/
          1' HOWEVER,REMEMBER THAT MAXIMUM'/
          2' COURSE ALTERATION PERMISSIBLE IS',
          3F4.1,' DEGREES')
          READ(MUNIT,*) NEWDIR
          WRITE(IU,50) NEWDIR
          TYPE 50,NEWDIR
50        FORMAT(10X,'NEW MISSILE COURSE SUPPLIED BY '/
          1' MISSILE COMMANDER=',F7.2,' DEGREES.')
          DIRM=NEWDIR
          MAUTO=1
          RETURN

110       MAUTO=0
          RETURN

120       WRITE(MUNIT,60)
60        FORMAT(10X,'DON''T ACT FUNNY WITH THE PROGRAM.'/
          110X,'AS A RESULT OF YOUR MISCHIEF,'/
          110X,'THE GAME HAS BEEN TERMINATED')
          STOP
          RETURN
          END



C   SUBROUTINE MISMOD : COMPUTES
C         NEXT COURSE FOR MISSILE

          SUBROUTINE MISMOD(XT,YT,DTHETA)
          COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
          COMMON /LAB1/DEGRAD
          COMMON /LAB3/IU

          CALL SLOPEC(XM,YM,XT,YT,DIRMOD)
          CALL ANGMOD(DIRM)
          DIFF=ABS(DIRMOD-DIRM)
          IF(DIFF<.1) GO TO 20
          IF(DIFF<DTHETA) GO TO10
          SIGN=1
          CSIGN=1.
          IF(DIFF.GT.180.) CSIGN=-1.
          IF(DIRMOD<DIRM) SIGN=-1
```

```
      DIRM=DIRM+DTHETA*SIGN*CSIGN
      RETURN

10    DIRM=DIRMOD
      RETURN

20    CALL SKIP10(JPRINT)
      IF(JPRINT.EQ.0) RETURN
      WRITE(IU,940)
940   FORMAT(80X,'MISSILE ON COURSE ! NO
     1COURSE CHANGE NEEDED.')
      RETURN
      END



C  S/R MISRCH : TO SIMULATE  CRUISE-
C               PHASE GUIDANCE FOR THE MISSILE

      SUBROUTINE MISRCH(DTHETA,XT,YT,JNAME,TLOCK)
      COMMON /LAB1/DEGRAD
      COMMON /LAB2/RSEEK
      COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
      COMMON /LAB3/ IU
      COMMON /LAB4/TDIR
      COMMON /LAB8/JSHIP,JCHAFF
      COMMON /LAB19/DIST
      INTEGER TLOCK

      IF(DIST.GT.RSEEK) GO TO 40
      CALL SLOPEC(XM,YM,XT,YT,TDIR)
      XTA=ABS(XT)
      YTA=ABS(YT)
      IF(TDIR.LE.DIRM) GO TO 10
      DIFF=DIRM+DTHETA
      IF(TDIR.GT.DIFF) GO TO 50
      GO TO 20
10    DIFF=DIRM-DTHETA
      IF(TDIR.LT.DIFF) GO TO 50
20    XLIM=ABS(XM+RSEEK*COSD(DIRM))
      YLIM=ABS(YM+RSEEK*SIND(DIRM))
      IF(XTA.LE.XLIM.OR.YTA.LE.YLIM) GO TO 60
40    WRITE(IU,930) JNAME
930   FORMAT(80X,A5,' BEYOND SEEKER RANGE')
```

```
      GO TO 70
50    WRITE(TU,910) JNAME
910   FORMAT(80X,A5,' OUTSIDE MISSILE SWEEP ANGLE')
70    TLOCK=0
      RETURN

60    WRITE(TU,920) JNAME
920   FORMAT(80X,A5,' WITHIN SEEKER-SEARCH-ZONE.')
      TLOCK=1
      RETURN
      END



C  S/R PCHAFF : TO COMPUTE COORDINATES WHERE
C                CHAFF IS TO BE FIRED AT
C  ENTER THIS ROUTINE ONLY WHEN TLOCK=1
C  (XC,YC) ARE RETURN PARAMETERS : DESIRED CHAFF
C                COORDINATES
C        JDONE1  FLAG SET TO 1 ONCE THE S/R
C                IS CALLED,ZERO OTHERWISE

      SUBROUTINE PCHAFF(TLOCK,DTHETA,JDONE1)
      COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
      COMMON /LAB7/XC,YC
      COMMON /LAB19/DIST
      INTEGER TLOCK

      CALL SLOPEC(XM,YM,XS,YS,TDIR)
      JDONE1=1
      TESTUP=TDIR+.1*DTHETA
      TESTDN=TDIR-.1*DTHETA
      IF(DIRM.GT.TESTUP) GO TO 20
      IF(DIRM.LT.TESTDN) GO TO 20
      RC=.75*SIND(DTHETA)*DIST
      XC=XS+RC*COSD(DIRS+180.)
      YC=YS+RC*SIND(DIRS+180.)
      RETURN

20    DIRC=2.*DIRM-TDIR
      XC=DIST*COSD(DIRC)
      YC=DIST*SIND(DIRC)
      RETURN
      END
```

```
C   S/R RANGE : TO COMPUTE LOS RANGE BETWEEN TWO POINTS

       SUBROUTINE RANGE(X1,Y1,X2,Y2,ADIST)
       DX=X1-X2
       DY=Y1-Y2
       DUM=DX*DX+DY*DY
       ADIST=SQRT(DUM)
       RETURN
       END



C   FILE 97.FOR
C   S/R RDTECT : TO DETECT PRESENCE OF A TARGET
C   THIS ROUTINE WILL HAVE TO BE CALLED FOR EVERY
C                RADAR/EW-RX ON-BOARD
C        PASSTV  FLAG=1 MEANS 'EMPLOY PASSIVE DETECTION
C                    =0 MEANS 'EMPLOU ACTIVE  DETECTION
C        DETECT  RETURN PARAMETER =1 TARGET DETECTED
C                                 =0 TARGET NOT DETECTED
C        MR      ROW VALUE OF MISSILE RADAR IN ON-BOARD
C                RADAR MATRIX
C        RS      RECEIVER SENSITIVITY
C        VLITE   VELOCITY OF LIGHT (3E8)
C        THRESH  VARIABLE TO REPRESENT 'PROBABILITY OF
C                DETECTION'
C        I       ROW VALUE OF THE SENSOR BEING USED FOR
C                DETECTION
C        IGW     ROW VALUE OF THE MISSILE IN GWEPON MATRIX

       SUBROUTINE RDTECT(I,PASSIV,DETECT)

       REAL LAMBDA
       INTEGER RADAR(5,15),ESM(2,10),GWEPON(2,20),
      1WEAPON(5,15),SHIP(15)
       COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
       COMMON /LAB3/IU
       COMMON /LAB14/SHIP,RADAR,WEAPON,GWEPON,ESM
       COMMON /LAB18/JUNIT
       COMMON /LAB19/DIST
```

```
      COMMON /LAB20/PI,FOURPI,VLITE,THRESH
      COMMON /LAB21/MR,IGW,MW
      INTEGER DETECT,PASSIV

      DATA JB1,JB2,JB4,JB8/1,2,4,8/
      DATA JYES,JNOT/3H   ,3HNOT/
      DATA JRADAR,JESM/5HRADAR,5HESMRX/

      TYPE 230,I,J,MR,IGW
230   FORMAT(20X,'INPUT PARAMETERS ARE ',4I2)
      IF(PASSIV==1) J=I
      IF(PASSIV.EQ.1) I=MR
      TYPE 230,I,J,MR,IGW
      PT=RADAR(I,7)*1000.
      GTEMP=RADAR(I,9)/10.
      GT=10.**(GTEMP)
      F=.5*(RADAR(I,3)+RADAR(I,4))
      TYPE 240,RADAR(I,3),RADAR(I,4),F
240   FORMAT(' CHECK PRINT',2I8,F10.1)
      LAMBDA=VLITE/F

      IF(PASSIV.EQ.1) GO TO 20
      SIGMA=GWEPON(IGW,2)/10.
      RS=RADAR(I,8)
      DENOM=FOURPI*DIST**4
      ANUMER=PT*GT*GT*LAMBDA*LAMBDA*SIGMA*10E-12
      PTEMP1=ANUMER/DENOM
      JSENS=JRADAR
      GO TO 40

20    IF(F.LT.ESM(J,4).AND.F.GT.ESM(J,3)) GO TO 30
      TYPE 220,F,ESM(J,3),ESM(J,2)
220   FORMAT(' MISSILE FREQUENCY(',F10.0,') OUTSIDE ',
     1'RANGE.'/ ' ESM FREQ COVERAGE BETWEEN',I8,
     2' AND',I8,' MHZ')
      RETURN

30    RS=ESM(J,5)
      GTEMP=ESM(J,6)/10.
      GR=10.**(GTEMP)
      AE=.25*LAMBDA*LAMBDA*GR*10E-12/PI
      DENOM=16*PI*PI*DIST*DIST
      PTEMP1=PT*GT*AE/DENOM
      JSENS=JESM
```

```
40      PTEMP2=PTEMP1/1000.
        PTEMP3=10.*ALOG10(PTEMP2)
        PR=ABS(PTEMP3)
        IF(PR.GT.RS) GO TO 50
        IF(RAN(DUM).GT.THRESH) GO TO 50
        DETECT=1
        RADAR(T,10)=1
        JFILL=JYES
        CALL SLOPEC(XM,YM,XS,YS,SLOPE)
        TYPE 210,JFILL,DIST,JSENS,PR,JSENS,RS,SLOPE
        CALL SKIP10(JPRINT)
        IF(JPRINT==0.AND.PASSIV==1) RETURN
        CALL BELL(JUNIT,JB2)
        WRITE(JUNIT,210)JFILL,DIST,JSENS,PR,JSENS,RS,SLOPE
        WRITE(TU,210)JFILL,DIST,JSENS,PR,JSENS,RS,SLOPE
210     FORMAT(81X,'TARGET ',A5,'DETECTED AT',F10.2,
        1' METERS'/
        281X,'POWER RECEIVED AT THE ',A5,'=',F8.2,
        3' DBM, WHEREAS'/
        481X,A5,' SENSITIVITY           =',F8.2,' DBM'/
        581X,'TARGET BEARING=',F5.1,' DEGREES')
        IF(PASSIV==1) GO TO 45
        RETURN

45      WRITE(TU,250) SLOPE,PR,RS
250     FORMAT(81X,'TARGET DETECTED AT BEARING='
        1,F5.1,' DEGREES'/81X,'POWER RECEIVED AT
        2ESM RECEIVER=',F8.2,' DBM'/81X,'WHEREAS
        3 RECEIVER SESITIVITY=',F8.2,' DBM')
        RETURN

50      DETECT=0
        JFILL=JNOT
        TYPE 210,JFILL,DIST,JSENS,PR,JSENS,RS
        CALL SKIP10(JPRINT)
        IF(JPRINT==0.AND.PASSIV==1) RETURN
        CALL BELL(JUNIT,JB2)
        WRITE(JUNIT,210)JFILL,DIST,JSENS,PR,JSENS,RS
        RETURN
        END
C   S/R SCENRO : TO DEFINE GAME SCENARIO

        SUBROUTINE SCENRO
C   PROG TO DEFINE GAME SCENARIO
C   FORMAT STATEMENT NOMENCLATURE
```

```
C         1XX       ACCEPT
C         2XX       TYPE
C         3XX       FILE READS
C         4XX       FILE WRITES

          INTEGER SHIP(15),RADAR(5,15),WEAPON(5,15),
          1ESM(2,10),GWEPON(2,20)
          DIMENSION INAM(4),IN(10)
          COMMON /LAB14/SHIP,RADAR,WEAPON,GWEPON,ESM
          COMMON /LAB15/MUNIT
          COMMON /LAB18/JUNIT
          COMMON /LAB21/MR,IGW,MW

          DATA INAM/5HRADAR,5HWEPON,5HGWPON,5HESM  /
          DATA JOK/2HOK/
          DATA JB1,JB2,JB4,JB8/1,2,4,8/

C   OPEN RELEVANT DATA-BASE FILES
          IR1=75
          IR2=100
          IR3=50
          OPEN(UNIT=20,FILE='NWGS01.DAT',ACCESS='RANDOM',
          1RECORD SIZE=IR1)
          OPEN(UNIT=21,FILE='NWGS02.DAT',ACCESS='RANDOM',
          1RECORD SIZE=IR1)
          OPEN(UNIT=22,FILE='NWGS03.DAT',ACCESS='RANDOM',
          1RECORD SIZE=IR1)
          OPEN(UNIT=23,FILE='NWGS04.DAT',ACCESS='RANDOM',
          1RECORD SIZE=IR2)
          OPEN(UNIT=24,FILE='NWGS05.DAT',ACCESS='RANDOM',
          1RECORD SIZE=IR3)

C   GAME TO BE DEFINED BY THE USER
5         CONTINUE
          CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,710)
710       FORMAT(' LET US DEFINE THE SCENE.'/
          1' TYPE BELOW THE NUMBER OF RADARS,'/
          2' WEAPONS AND ESM RECEIVERS'/
          3' THAT YOU DESIRE ON YOUR SHIP.'/
          4' (PRESENT MAX LIMIT IS 3,1,1)'/
          5' USE FREE FORMAT.')
          READ(JUNIT,*) NR,NW,NESM

7         CALL BELL(MUNIT,JB4)
```

```
        WRITE(MUNIT,810)
810     FORMAT(' LET US DEFINE THE SCENE.'/
        1' TYPE BELOW THE NO OF MISSILES THAT '/
        2' YOU WISH TO USE.'/
        3' (PRESENT MAX LIMIT IS 1 )'/
        4' USE FREE FORMAT')
        READ(MUNIT,*) NGW
        IF(NR.GT.3.OR.NW.GT.1
        1.OR.NESM.GT.1) GO TO 6
        GO TO 500

6       WRITE(JUNIT,216) NR,NW,NESM
216     FORMAT(' YOU HAVE EXCEEDED THE CAPACITY'/
        1' THAT THE GAME CAN HANDLE.'/
        2' MAXIMUM SENSORS ALLOWED ARE 3,1,1'/
        3' WHEREAS YOU SPECIFIED',3(I2,','),/
        4' PLEASE REDEFINE THE SCENARIO.')
        GO TO 5

        IF(NGW.EQ.1) GO TO 500
        WRITE(MUNIT,820) NGW
820     FORMAT(' YOU HAVE EXCEEDED THE LIMIT ON'/
        1' NO OF MISSILES. LIMIT IS 1 WHEREAS'/
        2' YOU SPECIFIED ',I2/
        3' PLEASE REDEFINE.')
        GO TO 7

C  READ IN THE RADARS
510     TYPE 240
240     FORMAT(' GAME SCENARIO NOT OKAY.'/
        1' PLEASE REDEFINE.')
        CALL BELL(JUNIT,JB2)
        WRITE(JUNIT,240)
        CALL BELL(JUNIT,JB4)
        WRITE(JUNIT,240)
500     CALL BELL(JUNIT,JB2)
        WRITE(JUNIT,211) NR,INAM(1)
211     FORMAT(' TYPE BELOW THE SERIAL NO OF ',I3,1X,
        1A5,'S'/' THAT YOU WANT ON THE SHIP.'/
        2' EACH SERIAL TO BE SEPARATED BY COMMAS')
        READ(JUNIT,*) (IN(I),I=1,NR)
        DO 10 I=1,NR
        J=IN(I)
        READ(21#J,310) (RADAR(I,K),K=1,15)
310     FORMAT(15I5)
```

```
      WRITE(JUNIT,220) INAM(1),J
220   FORMAT(' YOUR ',A5,'-',I2,' IS :')
      WRITE(JUNIT,310) (RADAR(I,K),K=1,15)
      TYPE 218,INAM(1),J
218   FORMAT(1X,A5,'-',I2,' CHOSEN BY',
     1' SHIP-COMMANDER IS :')
      TYPE 310,(RADAR(I,K),K=1,15)
10    CONTINUE

C  READ IN THE WEAPONS
19    CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,211) NW,INAM(2)
      READ(JUNIT,*) (IN(I),I=1,NW)
      DO 20 I=1,NW
      J=IN(I)
      READ(22#J,310) (WEAPON(I,K),K=1,15)
      WRITE(JUNIT,220) INAM(2),J
      WRITE(JUNIT,310) (WEAPON(I,K),K=1,15)
      TYPE 218,INAM(2),J
      TYPE 310,(WEAPON(I,K),K=1,15)
      IF(WEAPON(I,8)==1) GO TO 20
      CALL BELL(JUNIT,JB2)
      WRITE(JUNIT,720)
720   FORMAT(' YOU HAVE NOT CHOSEN ''CHAFF''
     1 AS THE WEAPON.'/' PLEASE DO SO NOW.')
      GO TO 19
20    CONTINUE

C  READ IN THE GUIDED WEAPONS
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT, 830)NGW,INAM(3)
830   FORMAT(' TYPE BELOW THE SL NO OF',
     1I2,1X,A5/' THAT YOU HAVE CHOSEN FOR
     2 ATTACK.')
      READ(MUNIT, *)(IN(I),I=1,NGW)
      IGW=1
      DO 30 I=1,NGW
      J=IN(I)
      READ(23#J,311) (GWEPON(I,K),K=1,20)
311   FORMAT(20I5)
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,220)INAM(3),J
      CALL BELL(MUNIT,JB4)
      WRITE(MUNIT,311)(GWEPON(I,K),K=1,20)
      TYPE 219,J
```

```
219       FORMAT(' GUIDED WEAPON-',I2,' CHOSEN BY',
          1' MISSILE COMMANDER IS :')
          TYPE 311,(GWEPON(I,K),K=1,20)
30        CONTINUE
C   READ IN THE WEAPON-ROW CORRESSPONDING TO THE GWEPON
          MW=NW+1
          J=GWEPON(1,1)
          READ(22#J,310) (WEAPON(MW,K),K=1,15)
C   READ IN GUIDED-WEAPON'S RADAR DATA
          MR=NR+1
          J=WEAPON(MW,11)
          WRITE(JUNIT,217) J
          TYPE 217,J

217       FORMAT(' ROW VALUE OF MISSILE RADAR IS =',I2)
          READ(21#J,310) (RADAR(MR,K),K=1,15)
          CALL BELL(MUNIT,JB4)
          WRITE(MUNIT,840) (RADAR(MR,K),K=1,15)
840       FORMAT(' RADAR ON YOUR MISSILE IS : '/
          115I5)
          TYPE 840,(RADAR(MR,K),K=1,15)

C   READ IN THE ESM SENSORS
          CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,211) NESM,INAM(4)
          READ(JUNIT,*) (IN(I),I=1,NESM)
          DO 40 I=1,NESM
          J=IN(I)
          READ(24#J,312) (ESM(I,K),K=1,10)
312       FORMAT(10I5)
          WRITE(JUNIT,220) INAM(4),J
          WRITE(JUNIT,312) (ESM(I,K),K=1,10)
          TYPE 218,INAM(4),J
          TYPE 312,(ESM(I,K),K=1,10)
40        CONTINUE

C   READ IN THE SHIP DATA
          CALL BELL(JUNIT,JB2)
          WRITE(JUNIT,212)
212       FORMAT(' TYPE THE SL NO OF THE PLATFORM'/
          1' THAT YOU WILL LIKE AS YOUR SHIP')
          READ(JUNIT,*) ISHIP
          READ(20#ISHIP,310) (SHIP(I),I=1,15)
          WRITE(JUNIT,230) (SHIP(I),I=1,15)
230       FORMAT(' YOUR SHIP IS : '/15I5)
```

```
      TYPE 230,(SHIP(I),I=1,15)

C FACILITY TO REDEFINE THE SCENE
      TYPE 213
213   FORMAT(' TYPE ''REDEFINE'' IF ALTERATION NEEDED'/
     1' ELSE TYPE ''OK''')
      ACCEPT 110,IREP
110   FORMAT(A2)
      IF(IREP.NE.JOK) GO TO 510
      TYPE 215
215   FORMAT(' GAME SCENARIO OKAY. PROCEED FURTHER.')
      CLOSE(UNIT=20)
      CLOSE(UNIT=21)
      CLOSE(UNIT=22)
      CLOSE(UNIT=23)
      CLOSE(UNIT=24)
      RETURN
      END


C  S/R SHRCS : TO COMPUTE SHIP'S RCS BASED ON
C                 ASPECT PRESENTED TO MISSILE

      SUBROUTINE SHRCS(TLOCK,SRCS)
      COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
      COMMON /LAB3/IU
      COMMON /LAB13/BOWON,BEAMON
      INTEGER TLOCK

      IF(TLOCK.EQ.0) GO TO 10
      DIFF=DIRS-DIRM
      CALL ANGMOD(DIFF)
      SRCS=ABS(BEAMON*SIND(DIFF))+BOWON
      RETURN

10    SRCS=0.
      WRITE(IU,90)
90    FORMAT(10X,'SHIP YET TO GET LOCKED-ON BY MISSILE!'/
     110X,'THEREFORE,SHIP-RCS HAS NO MEANING FOR MISSILE')
      RETURN
      END
```

```
C  S/R SKIP10 : TO SKIP TEN LINES WHILE OUTPUTTING

      SUBROUTINE SKIP10(JPRINT)
      COMMON /LAB5/TTIME

      JPRINT=0
      IDIV=TTIME/10.
      IF(IDIV.EQ.0) GO TO 34
      ITIME=TTIME
      ITEMP=ITIME-IDIV*10
      IF(ITEMP.NE.0) RETURN
34    JPRINT=1
      RETURN
      END


C  S/R SLOPEC : TO COMPUTE SLOPE FROM GIVEN POINTS

      SUBROUTINE SLOPEC(X1,Y1,X2,Y2,SLOPE)
      COMMON /LAB1/DEGRAD
      COMMON /LAB3/IU

      T1=X2-X1
      T2=Y2-Y1
      TEMP=ATAN2(T2,T1)
      SLOPE=DEGRAD*TEMP
      CALL ANGMOD(SLOPE)
      RETURN
      END


C   S/R UPDATE : UPDATES SHIP AND
C                MISSILE COORDINATES

      SUBROUTINE UPDATE
      COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
      COMMON /LAB10/DELT
      COMMON /LAB19/DIST
```

```
      XS=XS+VS*COSD(DIRS)*DELT
      YS=YS+VS*SIND(DIRS)*DELT
      XM=XM+VM*COSD(DIRM)*DELT
      YM=YM+VM*SIND(DIRM)*DELT
      CALL RANGE(XS,YS,XM,YM,DIST)
      CALL WEFECT(XS,YS)
      CALL WEFECT(XM,YM)
      RETURN
      END


C  S/R WEFECT : SIMULATION OF SURFACE WIND
C               AND IT'S EFFECT AT SEA
C       WSPEED  WIND SPEED IN KNOTS
C       DIRW    DIRECTION OF WIND

       SUBROUTINE WEFECT(X,Y)
       COMMON /A/XS,YS,VS,XM,YM,VM,DIRS,DIRM
       COMMON /LAB7/XC,YC
       COMMON /LAB9/ WSPEED,DIRW
       COMMON /LAB10/DELT

       X=X+WSPEED*DELT*COSD(DIRW)
       Y=Y+WSPEED*DELT*SIND(DIRW)
       RETURN
       END
```

# APPENDIX : C

## SAMPLE RECORD : GAME OUTCOME, ASMD - GAME

```
RUN  1
SHIP'S  INITIAL POSITION :  X=   2000.00  Y=  -3000.00 MTRS
          COURSE=   30.00 DEGREES
MISSILE'S  INITIAL POSITION :  X= -10000.00  Y=   2000.00 MTRS
          COURSE=   10.00 DEGREES

TIME      XS        YS        XM        YM      DIRS     DIRM  RANGE

MISSILE UNABLE TO LOCK-ON,
BECAUSE MISSILE COURSE=  10.00
WHEREAS HOME-ON COURSE= 337.39
TYPE 'C' FOR COMMAND-GUIDANCE,AND
'I' FOR INERTIAL-GUIDANCE.
NEW MISSILE COURSE SUPPLIED BY
 MISSILE COMMANDER=  10.00 DEGREES.
   1.     2009.0   -2994.7   -9712.8    2035.8    27.9     7.0 12755.7
```

```
WIND-SPEED=   1.0 KNOTS.
WIND-DIRECTION=  90.0 DEGREES

GAME PLAYED ON 30-Jul-79
GAME STARTED AT 20:08 39.6
DATA DTIME,COEFF,VOLUME/   10.  500. 5000./
PASSIV DETECTION :

 TARGET       DETECTED AT  13000.00 METERS
 POWER RECEIVED AT THE ESMRX=   81.84 DBM, WHEREAS
 ESMRX SENSITIVITY          =  100.00 DBM
 TARGET BEARING=337.4 DEGREES
 TARGET DETECTED AT BEARING=337.4 DEGREES
 POWER RECEIVED AT ESM RECEIVER=   81.84 DBM
 WHEREAS RECEIVER SESITIVITY=  100.00 DBM
SHIP  OUTSIDE MISSILE SWEEP ANGLE

PASSIV DETECTION :

 TARGET       DETECTED AT  12755.66 METERS
 POWER RECEIVED AT THE ESMRX=   81.68 DBM, WHEREAS
 ESMRX SENSITIVITY          =  100.00 DBM
 TARGET BEARING=336.8 DEGREES
 TARGET DETECTED AT BEARING=336.8 DEGREES
 POWER RECEIVED AT ESM RECEIVER=   81.68 DBM
 WHEREAS RECEIVER SESITIVITY=  100.00 DBM
SHIP  OUTSIDE MISSILE SWEEP ANGLE
```

```
2.     2018.1   -2989.8   -9424.2    2056.5    25.8     4.0 12505.7
                                                               PASSIV DETECTION :

                                                                TARGET      DETECTED AT  12505.68 METERS
                                                                POWER RECEIVED AT THE ESMRX=   81.50 DBM, WHEREAS
                                                                ESMRX SENSITIVITY          =  100.00 DBM
                                                                TARGET BEARING=336.2 DEGREES
                                                                TARGET DETECTED AT BEARING=336.2 DEGREES
                                                                POWER RECEIVED AT ESM RECEIVER=   81.50 DBM
                                                                WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                               SHIP  OUTSIDE MISSILE SWEEP ANGLE
3.     2027.5   -2985.2   -9134.9    2062.0    23.6     1.0 12250.4
                                                               PASSIV DETECTION :

                                                                TARGET      DETECTED AT  12250.43 METERS
                                                                POWER RECEIVED AT THE ESMRX=   81.32 DBM, WHEREAS
                                                                ESMRX SENSITIVITY          =  100.00 DBM
                                                                TARGET BEARING=335.7 DEGREES
                                                                TARGET DETECTED AT BEARING=335.7 DEGREES
                                                                POWER RECEIVED AT ESM RECEIVER=   81.32 DBM
                                                                WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                               SHIP  OUTSIDE MISSILE SWEEP ANGLE
4.     2036.9   -2981.0   -8845.7    2052.4    21.5    -2.0 11990.3
                                                               PASSIV DETECTION :

                                                                TARGET      DETECTED AT  11990.32 METERS
                                                                POWER RECEIVED AT THE ESMRX=   81.14 DBM, WHEREAS
                                                                ESMRX SENSITIVITY          =  100.00 DBM
                                                                TARGET BEARING=335.2 DEGREES
                                                                TARGET DETECTED AT BEARING=335.2 DEGREES
                                                                POWER RECEIVED AT ESM RECEIVER=   81.14 DBM
                                                                WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                               SHIP  OUTSIDE MISSILE SWEEP ANGLE
5.     2046.5   -2977.1   -8557.5    2027.7    19.4   355.0 11725.8
                                                               PASSIV DETECTION :

                                                                TARGET      DETECTED AT  11725.76 METERS
                                                                POWER RECEIVED AT THE ESMRX=   80.94 DBM, WHEREAS
                                                                ESMRX SENSITIVITY          =  100.00 DBM
                                                                TARGET BEARING=334.7 DEGREES
                                                                TARGET DETECTED AT BEARING=334.7 DEGREES
                                                                POWER RECEIVED AT ESM RECEIVER=   80.94 DBM
                                                                WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                               SHIP  OUTSIDE MISSILE SWEEP ANGLE
6.     2056.2   -2973.6   -8271.0    1988.0    17.3   352.0 11457.2
```

PASSIV DETECTION :

TARGET DETECTED AT 11457.23 METERS
POWER RECEIVED AT THE ESMRX= 80.74 DBM, WHEREAS
ESMRX SENSITIVITY = 100.00 DBM
TARGET BEARING=334.3 DEGREES
TARGET DETECTED AT BEARING=334.3 DEGREES
POWER RECEIVED AT ESM RECEIVER= 80.74 DBM
WHEREAS RECEIVER SESITIVITY= 100.00 DBM
SHIP OUTSIDE MISSILE SWEEP ANGLE

7. 2066.0 -2970.4 -7987.0 1933.3 15.2 349.0 11185.2

PASSIV DETECTION :

TARGET DETECTED AT 11185.21 METERS
POWER RECEIVED AT THE ESMRX= 80.53 DBM, WHEREAS
ESMRX SENSITIVITY = 100.00 DBM
TARGET BEARING=334.0 DEGREES
TARGET DETECTED AT BEARING=334.0 DEGREES
POWER RECEIVED AT ESM RECEIVER= 80.53 DBM
WHEREAS RECEIVER SESITIVITY= 100.00 DBM
SHIP OUTSIDE MISSILE SWEEP ANGLE

8. 2075.9 -2967.6 -7706.2 1863.8 13.0 346.0 10910.2

PASSIV DETECTION :

TARGET DETECTED AT 10910.23 METERS
POWER RECEIVED AT THE ESMRX= 80.32 DBM, WHEREAS
ESMRX SENSITIVITY = 100.00 DBM
TARGET BEARING=333.7 DEGREES
TARGET DETECTED AT BEARING=333.7 DEGREES
POWER RECEIVED AT ESM RECEIVER= 80.32 DBM
WHEREAS RECEIVER SESITIVITY= 100.00 DBM
SHIP OUTSIDE MISSILE SWEEP ANGLE

9. 2085.9 -2965.2 -7429.6 1779.7 10.9 343.0 10632.9

PASSIV DETECTION :

TARGET DETECTED AT 10632.87 METERS
POWER RECEIVED AT THE ESMRX= 80.09 DBM, WHEREAS
ESMRX SENSITIVITY = 100.00 DBM
TARGET BEARING=333.5 DEGREES
TARGET DETECTED AT BEARING=333.5 DEGREES
POWER RECEIVED AT ESM RECEIVER= 80.09 DBM
WHEREAS RECEIVER SESITIVITY= 100.00 DBM
SHIP OUTSIDE MISSILE SWEEP ANGLE

10. 2096.0 -2963.1 -7157.7 1681.2 8.8 340.0 10353.7

```
                                                                    PASSIV DETECTION :

                                                                     TARGET        DETECTED AT  10353.73 METERS
                                                                     POWER RECEIVED AT THE ESMRX=   79.86 DBM, WHEREAS
                                                                     ESMRX SENSITIVITY          =  100.00 DBM
                                                                     TARGET BEARING=333.4 DEGREES
                                                                     TARGET DETECTED AT BEARING=333.4 DEGREES
                                                                     POWER RECEIVED AT ESM RECEIVER=   79.86 DBM
                                                                     WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                                    SHIP  OUTSIDE MISSILE SWEEP ANGLE
                                                                    SHIP  OUTSIDE MISSILE SWEEP ANGLE
                                                                    SHIP  WITHIN SEEKER-SEARCH-ZONE.
                                                                    CHAFF FIRED AT  12. SECONDS
                                                                    DISTANCE BETWEEN SHIP AND POINT OF
                                                                    CHAFF DEPLOYMENT AT THE TIME OF
                                                                    CHAFF FIRING=    384.39 METRES
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    5540.97)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    5208.08)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    4869.41)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    4525.45)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    4176.65)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    3823.50)
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    3466.47)
20.   2196.9   -2963.1   -4563.5    406.2   347.6   333.3  7553.5
                                                                    PASSIV DETECTION :

                                                                     TARGET        DETECTED AT   7553.55 METERS
                                                                     POWER RECEIVED AT THE ESMRX=   77.12 DBM, WHEREAS
                                                                     ESMRX SENSITIVITY          =  100.00 DBM
                                                                     TARGET BEARING=333.5 DEGREES
                                                                     TARGET DETECTED AT BEARING=333.5 DEGREES
                                                                     POWER RECEIVED AT ESM RECEIVER=   77.12 DBM
                                                                     WHEREAS RECEIVER SESITIVITY=  100.00 DBM
                                                                    MISSILE ON COURSE ! NO COURSE CHANGE NEEDED.
                                                                    CHAFF YET TO BLOOM
                                                                    CHAFF YET TO GROW IN COMPARISON 'TO SHIP-RCS
                                                                    (       0.00    3106.07)
```

# APPENDIX : E

## GLOSSARY

ASMD (ANTI-SHIP MISSILE DEFENCE) : That aspect of Naval Warfare wherein the ship is required to defend itself against an attacking missile.

BLOOM TIME : Time taken by the CHAFF to bloom to the rated RCS after the CHAFF is launched.

CHAFF : An airborne cloud of lightweight reflecting objects typically consisting of strips of aluminium foil or metallic coated fibres which produce clutter in a region of space.

CRUISE MISSILE : A guided weapon which can steer it-self while 'cruising' towards the enemy. A major portion of the trajectory consists of the cruise phase.

ESM (ELECTRONIC warfare SUPPORT MEASURES) : That division of electronic warfare involving actions taken to search for,intercept,locate,and identify immediately radiated electromagnetic energy for the purpose of immediate threat recognition. Thus ESMs provide a source of information required for immediate action involving ECM,ECCM,avoidance,targeting,and other tactical employment of forces.

DEBRIEFING : Discussion of various aspects of mission/exer-cise after the completion of the mission/exercise for the purpose of analysis and refinement.

DECEPTION : Those measures designed to mislead the enemy by manipulation,distortion,or falsifacation of evidence to induce him to react in a manner prejudicial to his interests(see Electronic Deception).

DECOY : A device or devices used to divert or mislead enemy defensive systems so as to increase the probability of penetration and weapon delivery.

ECM (ELECTRONIC COUNTERMEASURES) : That division of EW involving actions taken to prevent or reduce an enemy's effective use of electromagnetic spectrum.

ELECTRONIC DECEPTION : The deliberate radiation,alteration absorption,or reflection of electromagnetic radiations in a manner intended to mislead an enemy in the interpretation of or use of information received by his electronic systems.

EW (ELECTRONIC WARFARE) : Military action involving the use of electromagnetic energy to determine,exploit, reduce,or prevent hostile use of the electomagnetic spectrum and action which retains freindly use of the electromagnetic spectrum. There are three divisions within EW : electronic warfare support measures,electronic countermeasures and electronic counter-countermeasures.

FPB : Fast patrol boats. Capable of doing high speeds. Generally fitted with surface-to-surface missiles and meant for operation in coastal waters.

FRIGATE : Warships of tonnage between 3000 and 5000 tons.

GATE STEALING : A method of diverting/deceiving the sensor transmitting electromagnetic energy.

HOMING : The process of steering towards the target by using some 'information' from the target. Homing could be active,passive or infrared.

HOME-ON-JAM (HOJ) : A method of passive guidance designed to use the jamming signal emitted by the target to track the target in angle.

INTERCEPT RANGE : (Of guided weapons) Range at which the guided weapon can engage the target.

JAMMING (ELECTRONIC JAMMING) : The deliberate radiation, reradiation,or reflection of electromagnetic

energy with the object of impairing the use of electronic devices, equipment or systems being used by the enemy.

NOISE JAMMING : Noise jamming is direct (straight), AM, OR FM noise on a carrier frequency that has a highly variable bandwidth for the purpose of increasing (saturating) the radar receiver's noise level. Noise jamming is extremely effective against most radars. It may be swept through the frequency spectrum at various rates or spot speeds . Noise jamming is identified by video saturation at all ranges in a sector of the scope;the size of the sector is dependent upon the power and range of the jammer. The techniques of taking random noise and radiating it for the purpose of jamming. May be amplified and radiated directly, or a carrier may be modulated with the noise.

NWGS : NAVAL WAR GAMING SYSTEM

PLATFORM : The basic fighting unit. Each platform (eg., ships, aircraft, helicopter, etc) is defined in terms of capabilities and characteristics (see Appendix A-1).

RADIO ALTIMETER : A missile borne transmitter/receiver setup to measure the altitude of the missile above the terrain below(sea).Generally employs frequency modulation and altitude is proportional to the frequency difference between the transmitted and received signals.

RCS (RADAR CROSS-SECTION) : The cross section of the target that is offered to the incident wave front and responsible for reflection.

REACTION TIME : (of weapons) Time lapse between identification of a target and firing/deployment of the weapon.

SCENARIO : The description of a conflict situation and a list of available forces with their capabilities.

SATURATION TIME : (of CHAFF) Time after which the Chaff cloud starts disintegrating.

SEA-SKIMMER-MISSILES : Guided weapons having : very low altitude of flight; over the horizon range; small RCS.

SENSORS : Electronic hardware aboard ships or shore installations in the electronic or sound emitting family (radars, sonars, etc).

SHORE BATTERY : A shore installation on a vantage point along the sea-coast fitted with guns/missiles for coastal/inshore defence. Weapons may, however, be used for attack also.

TRACKING : The process of following the target's path through a sensor once the target has been searched and located.

WAR GAME : An artificial, or more strictly, a theoretical conflict to afford a practice field for the acquisition of skill and experience in the conduct of direction of war, and an experimental and trial ground for the testing of strategic and tactical plans.

WEAPONS-FIT : The entire set of weapon(s) installed on-board a warship.